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AAEA Annual Meeting
Texas A & M University
College Station, Texas
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SIDHU · Technical Change in Punjab Wheat Production
RANDALL · Information, Power and Academic Responsibility
HAZELL AND SCANDIZZO · Demand Structures under Risk
BARITELLE AND PRICE · Supply and Marketing for Deciduous Crops
HARTMAN · Egg Cycle and Recursive Models

SHORT ARTICLES AND NOTES

- SASAKI AND SAEGUSA—Food Demand Matrix
- LEUTHOLD—Beef Cattle Futures Market
- BIERI AND SCHMITZ—Market Intermediaries and Price Instability
- BUXTON AND HAMMOND—Social Cost of Dairy Price Supports
- MACMILLAN, TUNG, AND TULLOCH—Migration Analysis and Farm Number Projection
- HOLLAND—Efficiency in Public School Finance
- TILL—Industries in the Nonmetropolitan South
- PEARSON AND MEYER—Comparative Advantage among African Coffee Producers
- HSU—Pricing Fertilizer in Taiwan
- THIESENHUSEN—Chile's Experiments in Agrarian Reform
- ASHRAF AND CHRISTENSEN—Dairy Farm Manure Disposal Regulations
- RYAN AND PERRIN—Fertilizer Response and Income Gains for Potatoes in Peru
- SAHI AND CRADDOCK—Estimating Flexibility Coefficients for Recursive Models

PROCEEDINGS OF THE WINTER MEETING

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Economics of Technical Change in Wheat Production in the Indian Punjab*

SURJIT S. SIDHU

A quantitative assessment of the "green revolution" associated with Mexican varieties of wheat in the Indian Punjab is attempted as alternative to the usual impressionistic assessments. Results indicate that the technical change has been cost-saving and has not been strongly biased in either a labor-saving or a capital-saving direction. Wheat production experienced a favorable cost curve shift on the order of about 16 percent. Input demands per acre increased by about 25 percent. Increased capitalized land values lead to inferences about income distribution and constitute a source for reinvestments designed to maintain the momentum of the "green revolution."

Key words: **technical change; green revolution; Mexican wheat; Indian Punjab.**

THERE seems to be a consensus in the literature on the "green revolution" that the spread since 1965 of high-yielding cereal varieties has ushered in an era of agricultural transformation in many parts of Asia. Fear of the Malthusian specter has been somewhat allayed and new hope for these countries generated. The realizable potential for greater agricultural output improves the prospects for sustained growth of these economies. The challenges facing policymakers and planners of the less developed countries are to convert the potential into a sustained basis for economic development and growth and to design programs that will distribute the gains from the new agricultural technology more evenly.

Answers to these challenges are by no means easy to intuit. At the very least is required an understanding of the nature and impact of the transformation that has already occurred or is under way. The need is not for a simple impressionistic assessment of this change but for quantitative measures which can be usefully employed in applications of economic theory to develop effective policies.

In this paper an attempt is made to determine empirically the parameters of the change from old to new varieties of wheat[1] in the case of the Indian Punjab where significant success with the new varieties of wheat has been achieved. In the second section production function estimates of old and new varieties of wheat are compared, and the shifts in the derived factor demand functions resulting from the introduction of the new varieties of wheat are studied. In the third section behavior of the new wheat production function is examined over the four year period 1967/68–1970/71. In the fourth section a direct comparison between the long-run cost functions of old and new varieties of wheat during the year 1967/68 is carried out, and the behavior of the long-run cost function for new wheat over the four year period 1967/68–1970/71 is examined.

Production Function Shift from Old to New Wheat

The main objective in this section is to evaluate the nature and magnitude of changes in technology of wheat production from old to new wheats and to ascertain the magnitude of consequent shifts in the factor demand functions. For this purpose a simple model based on the standard neoclassical production function of the Cobb-Douglas type is used. The model is applied to farm level cross-sectional data of old and new varieties of wheat for the year 1967/68[2] from Ferozepur district of Punjab. These data were collected by the Directorate of Economics and Statistics (Ministry of Food and Agriculture, Government of India) on 150 farms spread over 15 villages.

Let the production function for wheat be written in the Cobb-Douglas form as:

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[1] The Punjab farms are multi-enterprise farms. This study deals only with wheat, not all farm enterprises.

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[2] The comparative analysis of old *versus* new varieties of wheat is carried out only for the year 1967/68 because during the subsequent years, the number of farms growing old wheat and the area planted to it were substantially reduced.

(1) $Y = A\, N^{\alpha_1} L^{\alpha_2} K^{\alpha_3} F^{\alpha_4} \exp\,(\delta_j + u)$

where

Y = physical output of wheat measured in quintals per farm (including by-products.[3] By-products were converted into quintals of wheat by dividing the total value of by-products by wheat price.)

N = the labor input per farm used for wheat production measured in hours, and includes both family and hired labor. (Child and female labor was converted into man equivalents by treating 2 children [or women] equal to one man.)

L = the land input measured as acres of wheat grown per farm.

K = a measure of the flow of capital services going into wheat production per farm. (An hourly flow of services is derived for each durable input including capital in the form of livestock that the farm uses in wheat production. It includes depreciation charges, interest charges, and operating expenses. Depreciation schedules are based on the specific life of each input, but interest costs are estimated at a uniform interest rate of 10 percent per annum.[4] The actual number of hours of use times the hourly flow of services of each durable input gives its total service flow. Aggregation of these asset-specific service flows plus the seed costs yields a measure of the capital services.)

F = the current value in rupees of fertilizer and farm-produced manures per farm.

δ_j denotes the coefficient of the jth dummy variable designed to capture appropriate "effects,"[5] and u is the random disturbance term independently distributed with zero mean and finite variance. The usual error term is broken up into two components, a measure δ of the neutral variations in efficiency among farms, and the residual term u. This enables one to identify neutral productivity differences among old and new varieties of wheat, maintaining the assumption that non-neutral differences do not exist in the respective technologies. However, since the objective is to discover the nature of differences among these technologies, the hypothesis that technical change is of the neutral type is empirically tested.

The results from the ordinary least squares regressions linear in natural logarithms for equation (1) are presented in Table 1. Use of single equation models for agricultural production functions has been justified by Griliches [4], Mundlak and Hoch [9], and Zellner,

Table 1. Estimates of production function for wheat, 1967/68, Punjab, India[a]

Regression Number	Type of Wheat	Number of Observations	Constant	D^0	N	L	K	F	R^2 (adj)	SEE[b]	Returns to Scale	F-ratio[c]
I	Old	131	1.096		0.209	0.623	0.060	0.092	0.849	0.337	0.984	0.19
			(0.549)		(0.080)	(0.081)	(0.094)	(0.016)				
II	New	105	0.175		0.091	0.528	0.328	0.116	0.943	0.395	1.062	4.75[d]
			(0.625)		(0.091)	(0.091)	(0.110)	(0.045)				
III	Pooled	236	0.350		0.173	0.531	0.213	0.108	0.918	0.373	1.025	1.20
			(0.409)		(0.060)	(0.058)	(0.073)	(0.015)				
IV	Pooled	236	0.698	−0.186	0.163	0.593	0.195	0.088	0.921	0.365	1.039	3.20
			(0.415)	(0.056)	(0.059)	(0.060)	(0.071)	(0.016)				

[a] Regressions linear in logarithms are estimated by least squares. Dependent variable is output of wheat Y, in physical units. D^0 is a dummy variable with a value of one for "old wheat" and zero otherwise. N, L, K, and F are labor, land, capital costs, and fertilizer costs per farm. Standard errors of coefficients are in parentheses.

[b] Standard errors of estimates are in natural logarithms of output of wheat measured in quintals.

[c] F-ratio is calculated to test the hypothesis of constant returns to scale.

[d] Significant at 95 percent level.

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[3] The major by-product is wheat straw, which in chaffed form is fed to cattle. Sometimes sarson (an oil-seed crop) is also grown mixed with wheat.

[4] Kahlon, Miglani, and Mehta [8, p. 70] report that 68 percent of the amount borrowed in case of Ferozepur Sample for the year 1968/69 was at an interest rate of 9–10 percent per annum. The range of interest charges varied from 6.5 to 20 percent.

[5] These are, for example, "effects" due to genetic differences in seed of old and new varieties.

Kmenta, and Dreze [14], who argue that because inputs in agriculture are largely predetermined because of a considerable lag in production and because error is largely weather-determined, simultaneous equation bias will be small for well specified production functions.

The production environment in the present study does not seem to differ from the specification requirements postulated by them. Equation (1) is thus taken to be well specified. The estimates are quite reasonable in the sense that the output elasticities with respect to all inputs have the right signs and have low standard errors.

Three important conclusions come out of these results. First, in order to determine whether the technical change resulting from the introduction of new (Mexican) varieties of wheat is of the neutral or non-neutral type, separate regressions I (old wheat) and II (new wheat) are compared with the pooled regression IV. Analysis of covariance[6] gives an F-ratio of 1.39 with 4 and 226 degrees of freedom, which is not significant at the 90 percent level. Therefore, one cannot reject the hypothesis that output elasticities with respect to various inputs are the same in separate regressions for old and new wheats, if the constant terms in the two regressions are allowed to differ.

Second, from regression IV it can be observed that intercept term for new wheat is higher by 22.85 percent. This is the magnitude of the neutral upward shift in the wheat production function resulting from the introduction of new wheat. Since the shift in production function is of the neutral type, it implies that new varieties give a higher output per unit of each input than the old varieties. In the case of fertilizer, whether the new varieties give a higher level of output per unit of fertilizer compared to the old varieties (particularly at low level of applications) has been a major question surrounding the "green revolution." The results from the data analyzed in this research seem to provide a positive answer to this question. These results are also consistent with the findings reported by Kahlon and Kaul [7] in their analysis of the fertilizer response data at Punjab Agricultural University, Ludhiana.

Concomitant with the finding that new varieties give a higher level of output per unit of fertilizer is the fact that new varieties can stand heavier fertilizer applications per unit of land without lodging and thus have a much higher level of "yield ceiling" compared to the old varieties. It is well known that the old varieties have long, tender straw and are susceptible to lodging under higher fertilizer applications. This characteristic works as a limiting factor beyond a "yield ceiling" and constitutes a major barrier to increased wheat production. The information presented in Table 2 seems to suggest support for this hypothesis of a sudden decline in the fertilizer response curve in the case of old varieties at a lower level of output per unit of

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[6] See Johnston [6, pp. 136, 137] and Chow [3] for an explanation of this test.

Table 2. Average and marginal value products for different inputs in the production of old and new wheat, 1967/68, Punjab, India (calculated at geometric means)

	Geometric Means		Average Value Products		Marginal Value Products Using Output Elasticities from: Regression IV (Table 1)		
Input	Old Wheat	New Wheat	Old Wheat	New Wheat	Old Wheat	New Wheat	Geometric Mean Price from the Sample
			rupees per unit of input				
Labor (hrs)	1064.30	590.11	4.09	4.21	0.65	0.67	0.69[a]
Land (acres)	6.62	2.67	658.66	931.59	388.61	549.60	139.15[b]
Capital, K (Rs)	1107.60	590.50	3.93	4.21	0.79	0.84	
Fertilizer (Rs)	100.48	184.93	43.39	13.45	3.91	1.18	
Output (quintals)	54.60	32.57					
Output price[c] (Rs/quintal)	79.86	76.37					

[a] Sample wage rate per hour.
[b] Sample land rent per acre.
[c] Sample arithmetic means.

land compared to the new varieties. Seemingly unreasonable magnitudes for the marginal (and average) products of fertilizer in the production of old wheat—about three and a half times larger than new wheat—have no other obvious explanation. In retrospect it seems to clarify the situation that prevailed in Punjab during early 1960's prior to the introduction of new wheats. At that time it was a major complaint of the growers facing low fertilizer/output price ratio (fertilizer price was institutionally fixed) that they were unable to increase fertilizer applications to old wheat because of the phenomenon of lodging.

Third, the hypothesis of constant returns to scale is tested for each of the four regressions presented in Table 1. The hypothesis is rejected only in the case of regression II (new wheat) at the 95 percent level, indicating mildly increasing returns to scale. This probably occurs because with new wheat there is a relatively large number of observations with output level below the sample mean. The remaining three regressions indicate constant returns to scale.

Input demand functions

The question whether the "green revolution," that is, the introduction of high-yielding varieties of wheat, resulted in a significant shift in the demand for labor (and other factors of production) has been somewhat controversial in the literature. Bardhan [1], for example, has argued that the "green revolution" has not created any improvement in the employment situation of agricultural labor in India. However, the question is of crucial importance in view of the rapidly growing labor force. In this section an attempt is made to ascertain the magnitude of shifts in the input demands in wheat production resulting from introduction of high-yielding varieties of wheat.

Derived input demand functions can be obtained by solving simultaneously the production function and marginal productivity conditions. For the Cobb-Douglas case with constant returns to scale, these demand functions for N, K, and F can be obtained on a per acre basis by using the per acre sample mean levels of output of wheat Y for old and new wheats and their respective prices.

For this purpose a least squares regression was run for the pooled data, with the estimates restricted to constant returns to scale. These results are

$$(2)\quad \ln(Y/L) = \underset{(.383)}{1.001} - \underset{(.055)}{.164}D^0 + \underset{(.057)}{.139}\ln(N/L) + \underset{(.071)}{.173}\ln(K/L) + \underset{(.016)}{.088}\ln(F/L)$$

$$R^2 = .370$$

where D^0 is a dummy variable with a value of one for old wheat and zero for new wheat, and figures in parentheses are standard errors.

From (2) the production function estimates for new and old wheats can be written as[7]

$$(3)\quad Y_N = 2.718\, N^{.139} L^{.600} K^{.173} F^{.088}$$
$$(4)\quad Y_O = 2.316\, N^{.139} L^{.600} K^{.173} F^{.088}.$$

Equations (3) and (4) are obtained by requiring constant returns to scale in (all) the inputs of labor, land, capital, and fertilizer, and the input elasticities in (3) and (4) differ slightly from the unrestricted estimates of regression IV in Table 1. The input demand functions for N, L, K, and F by farms producing *new wheat* obtained from (3) are given by

$$(5)\quad \begin{aligned} N &= .152\, Y P_n^{-.861} P_l^{.600} P_k^{.173} P_f^{.088} \\ L &= .656\, Y P_n^{.139} P_l^{-.400} P_k^{.173} P_f^{.088} \\ K &= .189\, Y P_n^{.139} P_l^{.600} P_k^{-.827} P_f^{.088} \\ F &= .096\, Y P_n^{.139} P_l^{.600} P_k^{.173} P_f^{-.912} \end{aligned}$$

where P_n, P_l, P_k, and P_f are prices of labor, land, capital, and fertilizer, respectively.

Similar demand functions for N, L, K, and F by farms producing *old wheat* obtained from (4) are given by

$$(6)\quad \begin{aligned} N &= .178\, Y P_n^{-.861} P_l^{.600} P_k^{.173} P_f^{.088} \\ L &= .770\, Y P_n^{.139} P_l^{-.400} P_k^{.173} P_f^{.088} \\ K &= .220\, Y P_n^{.139} P_l^{.600} P_k^{-.827} P_f^{.088} \\ F &= .112\, Y P_n^{.139} P_l^{.600} P_k^{.173} P_f^{-.912} \end{aligned}$$

---

[7] The coefficient for land L is derived implicitly from estimates of (2). Per acre production function with four inputs can be written

$$\frac{Y}{L} = A\left(\frac{N}{L}\right)^{\alpha_1}\left(\frac{K}{L}\right)^{\alpha_3}\left(\frac{F}{L}\right)^{\alpha_4}.$$

Thus

$$Y = A\, N^{\alpha_1} L^{(1-\alpha_1-\alpha_3-\alpha_4)} K_1^{\alpha_3} F^{\alpha_4},$$

that is, coefficient for land

$$\alpha_2 = (1-\alpha_1-\alpha_3-\alpha_4).$$

From (5) and (6) the per acre demand functions for N, K, and F can be obtained by substituting for Y the sample mean output per acre for the respective wheat type and then multiplying the right hand side by the sample mean prices[8] of the respective wheats. These computations indicate that the per acre demand functions for the new wheat are higher by 25 percent than the ones for the old wheat.

This shift in the factor demand functions in wheat production has important implications for factor markets. Rapidly growing labor force (both rural and urban) and slow rate of growth in demand for urban-industrial employment place a major burden for absorption of labor force on agriculture and agriculture-related activities, at least during the decade of 1970's. A 25 percent shift in the labor demand function as a result of the introduction of new varieties of wheat is a significant step forward for expansion of labor absorption *in wheat production.* Estimates of the extent to which employment opportunities increased in farming by increased multiple cropping (made possible by the shorter growing period of new wheats) and in other agriculture-related sectors of the economy do not seem to be feasible at this time. Some observers [Shaw, 12, p. 52] feel that such indirect effects on expansion of employment perhaps exceed the direct effects. Thus, there seems to be substantial labor-absorptive capacity in the "green revolution."

Following their introduction, the new varieties of wheat continued to replace old wheat at a rapid rate. At the same time total area under wheat continued to expand, replacing barley and gram as competing winter crops. But since both these crops employ less labor per unit of land compared to old varieties of wheat, this does not seem to constitute a deterioration in labor employment. However, area in cotton in summer season has declined. Some labor replacement may have resulted from replacement of cotton by wheat at the margin and employment of less labor in wheat production.

The shift in demand functions for chemical fertilizer and various forms of capital have implications quite contrary to the shift in labor demand function. Whereas the labor demand shift helps to cope with rapid shifts in labor supply, the shift in demand for fertilizer and capital inputs is suggestive of the impending necessity of managing larger supplies of these inputs.

The case of land, however, is different. The estimated marginal value product of land is considerably larger for new wheat and much above the sample's geometric mean value of land rent per acre. Due to the relatively inelastic supply of land, increased productivity of land resulting from the introduction of new wheats was reflected in subsequent years in rising land values. This became a windfall gain to the owners of farm land—a gain at almost no cost to the owners.[9] These gains were in addition to gains in net incomes that resulted from the new wheats, which increased linearly with the amount of land operated. Thus even though the shift in the wheat production function resulting from introduction of new varieties has been neutral in character, the "effects" of the "green revolution" seem to have increased existing inequalities of income distribution in favor of larger land owners.

In a society so vehemently concerned with an equitable partitioning of these gains, there seems to be an obvious need for fiscal and agrarian measures to correct these increasing inequalities. In addition, it will be rather unfortunate if some part of these gains is not siphoned off for investments designed to create new income streams and to establish the conditions necessary to maintain the momentum of the "green revolution."

New Wheat Production Relationship, 1967/68–1970/71

The new high-yielding varieties of wheat continued to replace the old varieties at a rapid rate after their introduction in 1966/67. Wheat area planted to new wheat in Punjab was 3.6 percent, 35.4 percent, 48.5 percent, and 65.5 percent during the years 1966/67, 1967/68, 1968/69, and 1969/70, respectively [13, Appendix 1]. In this section an attempt is made to provide estimates of the new wheat production function and to analyze the behavior of this relationship over the four year period 1967/68–

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[8] These sample means for the year 1967/68 are

	New Wheat	*Old Wheat*
Output per acre (quintals)	13.00	8.50
Price per quintal (Rupees)	76.37	79.86

[9] See Herdt and Cochrane [5] for a perspective on capitalization of the gains of technological advance in the form of increased land values.

1970/71.[10] The basic model used for this purpose is equation (1) from the previous section.

Results of the least squares estimates from equation (1) are summarized in Table 3. Coefficients for the "year dummy variables" have negative signs and are significantly different from zero at the 99 percent level. An analysis of covariance test comparing the separate regressions I, II, III, and IV with overall regression V gave an F-ratio of 5.30 with 15 and 636 degrees of freedom which is significant at the 99 percent level. Thus, the hypothesis of equality between the sets of coefficients in the four yearly regressions is rejected, indicating that the production function for the new wheat has been unstable over the four year period. It is, however, necessary to go a step further. The analysis of covariance comparing separate yearly regressions with overall regression VI gave an F-ratio of 2.27 with 12 and 636 degrees of freedom which is significant at the 95 percent level (but not 99 percent). That is, the hypothesis of equality between slope coefficients allowing the intercepts in yearly regressions to vary is also rejected.

Exogenous factors like weather and change

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[10] The data for the years 1967/68 and 1968/69 were collected by the Directorate of Economics and Statistics (Ministry of Food and Agriculture, Government of India) on 150 farms in Ferozepur district of Punjab. For the year 1969/70, data were made available for 320 farms spread over the entire state of Punjab, by the courtesy of the Economic Adviser, Government of Punjab. For the year 1970/71, data were collected under the supervision of this author over four different locations in Punjab.

Table 3. Estimates of production function for new wheat, 1967/68–1970/71, Punjab, India[a]

Year	1967/68	1968/69	1969/70	1970/71	Overall		
Regression Number	I	II	III	IV	V	VI	VII[b]
Number of Observations	105	136	287	128	656	656	656
Constant	0.175 (0.625)	0.678 (0.898)	1.064 (0.305)	—1.733 (0.564)	0.333 (0.230)	0.304 (0.253)	—2.549 (0.092)
D_1						—0.298 (0.047)	—0.477 (0.049)
D_2						—0.282 (0.044)	—0.462 (0.046)
D_3						—0.171 (0.048)	—0.411 (0.049)
Labor	0.091 (0.091)	0.198 (0.146)	0.113 (.052)	0.473 (0.094)	0.209 (0.040)	0.190 (0.040)	0.194 (0.032)
Land	0.528 (0.091)	0.577 (0.135)	0.723 (0 062)	0.305 (0.099)	0.604 (0.039)	0.613 (0.043)	0.500 (0.032)
Capital, K	0.328 (0.110)	0.108 (0.127)	0.127 (0.051)	0.173 (0.072)	0.099 (0.015)	0.161 (0.039)	0.244 (0.035)
Fertilizer	0.116 (0.044)	0.110 (0.033)	0.031 (0.018)	0.110 (0.032)	0.082 (0.016)	0.066 (0.014)	0.068 (0.014)
R^2 (adj.)	0.943	0.875	0.877	0.922	0.908	0.915	0.916
SEE^c	0.395	0.405	0.324	0.255	0.359	0.347	0.343
Returns to scale	1.062	0.993	0.993	1.061	0.994	1.030	1.006
F-ratio[d]	4.75[e]	0.04	0.09	4.51[e]	0.23	2.50	0.15

[a] Equations linear in logarithms are estimated by least squares. Dependent variable is output of wheat in physical units. D_i ($i = 1, 2, 3$) are the year dummies taking the value of one for 1968/69, 1969/70 and 1970/71 respectively and zero otherwise. Standard errors of coefficients are in parentheses.

[b] The inputs for this regression are measured in value terms.

[c] Standard errors of estimate are in natural logarithms of wheat output measured in quintals.

[d] The calculated F-ratio is for testing the hypothesis of constant returns to scale.

[e] Indicates the F-ratio is significant at 95 percent level.

(some deterioration)[11] in seed quality may account for the downward shift in the years subsequent to 1967/68 as indicated by the negative coefficients of the "year dummy variables." Another explanation could be that during the year 1967/68 the new wheats were planted on the best available wheat lands, and marginally inferior lands were added during the next two years. It seems reasonable that all three factors —adverse weather, deterioration of seed, and addition of marginally inferior lands in production—may have contributed to a downward shift in the production function after 1967/68, but an assessment of their relative influences seems impossible.

It may be pointed out that the absolute size of the coefficient of the dummy variable for the year 1970/71 is much smaller than the coefficients for 1968/69 and 1969/70, which means that the downward shift of the production function was to some extent reversed. The question is whether the downward movement was a temporary phenomenon or is a long-run technological regression in the production of new wheats. The problem seems to be worth investigation by wheat breeders and agronomists.

For regression VII all inputs are measured in value terms. This resulted in lower standard errors of all the coefficients and slightly better fit for the equation. One possible explanation for this could be that part of the quality adjustments for the inputs (in particular land) is taken care of by the value measures.

As noted above, statistical evidence indicates that there have been some yearly changes in the output elasticities as well as in the efficiency parameters. Application of least squares to individual farm observations for estimating the parameters of a Cobb-Douglas production function is, however, an averaging process. Estimates obtained from this averaging process, using four years' data, should have better predictive value than those obtained from a single cross-section. For this reason estimates obtained from the four years' pooled data, particularly those employing value measures of inputs—regression VII in Table 3—are considered relatively better estimates.

In regard to the question of economies of scale in new wheat production, at a 95 percent level of significance mildly increasing returns to scale are indicated for the years 1967/68 and 1970/71. For these years a relatively large number of observations had output below the respective sample means, and these probably account for the mildly increasing returns. For the remaining two years constant returns to scale are indicated.

Cost Function Estimates

One of the major earlier controversies of the "green revolution" was whether the unit cost of production was lower in the case of new varieties of wheat compared to the old varieties, or whether the new varieties simply produced a larger output per unit of land with concomitant increase in the level of input applications. Results presented in the second section indicate an upward shift in the production function for wheat resulting from the introduction of new varieties. This implies a reduction in the unit costs of producing wheat at given input prices. In this section an attempt is made to obtain an estimate of the magnitude of shift in the long-run cost function, from old to new varieties of wheat, using data for the year 1967/68. Also, in order to develop a perspective about the behavior of cost relationships of the new varieties after their introduction in 1966/67, the four yearly cost functions for new wheat are compared for the period 1967/68–1970/71.

The total cost function used by Nerlove [10] for the Cobb-Douglas production function (1) can be written in natural logarithms for the variables as:

$$\begin{aligned} \ln C = A + \beta_0 \ln Y + \beta_1 \ln P_n \\ + \beta_2 \ln P_l + \beta_3 \ln P_k + \beta_4 \ln P_f \\ - \lambda_i D_i - e \end{aligned} \tag{7}$$

where

C = the total cost per quintal of wheat produced per farm in rupees. It is the sum of wage bill, total land rent, capital costs K, and fertilizer bill F.

Y = as defined above.

P_n = the hourly wage rate of labor, obtained by dividing the total wage bill by total labor input N. (Total wage bill for labor includes payments to labor hired on daily wage basis, labor hired on annual contract basis, and the imputed value of services of family labor).

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[11] During farm visits in 1970 and 1971 Punjab farmers generally complained of defective seed quality after 1967/68, that is, that seed did not perform as well during later years. I think mixing of lower quality seed with better seeds occurred at more than one level of the seed distribution channel. During the 1968/69, 1969/70, and 1970/71 crop years, weather was somewhat adverse relative to 1967/68.

P_l = the average rental price of land per acre per farm, obtained by dividing the total rental value of land per farm by the wheat land per farm (L). (Total rental value of land services for wheat production per farm includes the actual rent paid for rented-in land in cash or share of the produce and the imputed rental value of owned land. For lands producing two crops during the year, half of the annual rent is treated as the share of the wheat crop.
P_k = "price" of capital input.
P_f = price of fertilizer,
and
D_i = the dummy variable(s) introduced to compare the cost function of old and new wheats, and the four yearly cost functions for the period 1967/68 to 1970/71 in the case of new wheat.

Equation (7) cannot be used for empirical estimation because data on capital price P_k are not available for individual farms and fertilizer price P_f was uniform for all farms as a result of government policy. This raises a serious specification problem [Griliches 4]. In particular the elimination of capital price P_k from the equation biases the coefficients of the remaining variables; considering the likely imperfections[12] in the capital market, it can be argued *a priori* that output Y and capital price P_k are negatively correlated. However, the model does provide direct estimates of the percentage shifts in the cost functions of old and new wheats and of the yearly percentage shifts in the cost function of the new wheat.

Least squares regression estimates comparing cost functions for old and new wheats are presented in Table 4, and the ones comparing the four yearly cost functions for new wheat are presented in Table 5. Estimates in Table 4 indicate that intercepts of old and new wheat cost functions differ by 18.40 percent. An analysis of covariance test comparing the separate regressions for old and new wheats (I and II) with the overall regression IV yields an F-ratio of 0.79 with 3 and 228 degrees of freedom. This means that the two cost functions differ in the intercepts and not in slopes: the introduction of high-yielding wheats shifted the long-run unit cost function neutrally downward by 15.54 percent. This provides a rough indication of the magnitude of gains to the society from the introduction of new wheats. For example, during the year 1970/71 India produced about 21 million tons of wheat, nearly all of which was

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[12] The capital market does exhibit imperfections: long-period loans are not easily available to smaller and poorer farmers, transaction costs are independent of the loan amounts, and certain types of capital costs are indirectly subsidized for larger producers. Supply of electricity for irrigation purposes is a case in point. Electricity charges are at a fixed rate of approximately Rs 8.50 per month per horse power of the motor used and are thus independent of the electricity used. See Brar and Sandhu [2] for details of rate structure for different sizes of electric motors. See Rao [11] for the argument that farm machinery has been made artificially cheap through liberal import policy and through the extension of institutional credit for the purchase of tractors on unduly liberal terms.

Table 4. Estimates of cost function for wheat based on equation (7), 1967/68, Punjab, India[a]

Regression Number	Type of Wheat	Number of Observations	Constant	Coefficient of D^0	Y	P_n	P_l	R^2 (adj)
I	Old	131	3.871 (0.361)		0.821 (0.031)	0.059 (0.090)	0.155 (0.057)	0.845
II	New	105	3.907 (0.515)		0.868 (0.023)	0.118 (0.119)	0.089 (0.085)	0.943
III	Pooled	236	3.764 (0.306)		0.872 (0.018)	0.077 (0.075)	0.126 (0.050)	0.918
IV	Pooled	236	3.695 (0.296)	0.184 (0.044)	0.857 (0.017)	0.089 (0.072)	0.130 (0.048)	0.923

[a] Regressions linear in logarithms are estimated by least squares. Dependent variable is total cost C of wheat in rupees per farm. D^0 is a dummy variable with a value of one for "old wheat" and zero otherwise. Y, P_n, and P_l are the output of wheat per farm in physical units, wage rate per hour, and the rent of wheat land per acre, respectively. Standard errors of coefficients are in parentheses.

Table 5. Estimates of the cost function for new wheat, 1967/68–1970/71, Punjab, India[a]

Regression Number	Year	Number of Observations	Intercept	D_1	D_2	D_3	Coefficients of Y	P_n	P_l	R^2 (adj)
I	1967/68	105	3.907 (0.516)				0.868 (0.023)	0.118 (0.119)	0.089 (0.085)	0.943
II	1968/69	136	3.616 (0.635)				0.858 (0.029)	0.437 (0.127)	0.226 (0.104)	0.884
III	1969/70	287	4.103 (0.305)				0.856 (0.019)	0.127 (0.079)	0.111 (0.051)	0.874
IV	1970/71	128	4.800 (0.319)				0.910 (0.025)	0.244 (0.118)	0.046 (0.069)	0.937
V	pooled	656	3.445 (0.188)				0.894 (0.011)	0.236 (0.051)	0.243 (0.035)	0.913
VI	pooled	656	3.879 (0.178)	0.402 (0.043)	0.416 (0.040)	0.327 (0.046)	0.865 (0.011)	0.211 (0.049)	0.121 (0.035)	0.926

[a] Regressions of logarithms of total cost (C) on logarithms of output (Y), wage rate (P_n), and per acre land rent (P_l) are estimated by least squares. Standard errors of coefficients are in parentheses.

new wheat worth about 16 billion rupees; this amount of old wheat could have been produced only with 18.40 percent more resources.

Comparing separate regressions I, II, III, and IV with the pooled regression V (Table 5) gives an F-ratio of 10.51 with 12 and 640 degrees of freedom which is significant at 99 percent level, implying that there are significant differences in the four years' cost functions. But comparing separate regressions I, II, III, and IV with the pooled regression VI, which has the intercept-shifting year dummies in it, gives an F-ratio of 1.12 with 9 and 640 degrees of freedom, which is not significant at the 90 percent level. These tests indicate that the annual variations in the new-wheat cost function have been neutral in character, that is, the intercept terms of the logarithmic functions changed significantly from year to year but not the regression coefficients. Thus the estimated coefficients of the dummy variables D_i ($i = 1, 2, 3$) for regression VI can be interpreted to represent percentage upward shifts in the yearly total cost functions relative to the year 1967/68 (at existing factor prices). These shifts are the combined result of decline in the efficiency parameter of the production function as indicated in the third section and a rise in the average level of input prices relative to 1967/68. The rupees per quintal costs calculated at the geometric means from each year's sample were 50.91 for 1967/68, 72.97 for 1968/69, 70.81 for 1969/70, and 69.41 for 1970/71.

Summary and Conclusions

An attempt has been made here to give empirical content to the change in production technology of wheat resulting from the introduction of Mexican wheat varieties in the Indian Punjab. The models are simple and represent applications of the standard neoclassical theory of cost and production. Empirical evidence is based on farm-level primary data—for the years 1967/68 to 1970/71—the scope of which covers almost the entire state of Punjab and which have been generated by careful record keeping.

Results indicate that the technical change has been approximately neutral—it has not been strongly biased in either a labor-saving or a capital-saving direction. It has been cost saving. Technical efficiency has increased by almost one-fourth, and unit costs of production have declined by about 16 percent. The demand per acre for labor, fertilizer, and capital inputs increased by about 25 percent.

The results also indicate that the unit costs of production of new varieties started to rise after the growing season 1967/68. This was the result of a rise in the average level of input prices and some decline in the efficiency parameter of the production function. The upward shifts in the long-run cost function relative to 1967/68 have been of the order of about 40 percent for 1968/69, 41 percent for 1969/70, and 32 percent for 1970/71.

The new wheat technology also appears to be neutral with respect to farm size. From the data used in this study, there seems to be no strong evidence against the phenomenon of constant returns to scale in the production using new wheat varieties. We cannot argue against small farms on the grounds of economies of scale. In order to maintain the momentum of the "green revolution," measures are needed to siphon off the gains from incomes and capitalized land values for reinvestments designed to create new income generating streams. Measures are also required for an equitable distribution of these gains.

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Information, Power and Academic Responsibility*

ALAN RANDALL

The provision of information, no matter how objective, influences power relationships in an economy. Thus, scientific activity is non-neutral in its effects on the outcome of economic interaction. Therefore the researcher and his host institution cannot avoid moral choices as to what research is performed, what information is provided, and to what use that information is put.

Key words: **economic power; information; research; moral responsibility.**

IN RECENT ISSUES of this *Journal*, Emery Castle has examined two questions of importance to scientists working in an academic context: scientific objectivity [2, p. 809] and the inherent competition between the autonomous and popular functions of the university [3, p. 551]. The objective of this paper is to examine a third, not unrelated, question: the moral responsibilities of the scientist and his host institution in the production, interpretation, and dissemination of information. A paradigm of the economy is introduced which explicitly acknowledges the role of power in economic interaction. In a very real sense, scientific activity is not neutral in its effects upon power relationships. This non-neutrality of scientific activity directly confronts the scientist and his host institution with the necessity of making distinct moral choices about the type of research carried out and the type of information provided as a result of this research.

Power in Economic Interaction

To consider the impact of the provision of information on the allocation of resources and the distribution of opportunity and income among individuals and identifiable groups, a model of economic interaction is necessary. The model used must be suitable for the positive analysis of distribution of opportunity, power, property, and income. While the competitive model of neoclassical theory has been the most widely used model in modern economics,[1] it is of limited use in this endeavor, since it abstracts from the very issues that are under consideration here.[2] The concept of Pareto-efficiency, the pinnacle of pure competitive theory, acquires empirical meaning only when the initial distributions of income, property, and power are held constant. A model which focuses upon rather than abstracts from these variables is essential to the author's purposes.

An alternative paradigm of economic interaction is now presented.[3] It is useful to focus on the concept of *choice*. Choice is the circumstantially limited exercise of selection among available alternatives. The scope of one's choice, that is, one's freedom, at a given instant in time is determined by one's *opportunity set*. The opportunity set consists of the range of alternatives provided by the society of which the individual is a member and their relative costs; it is bounded by the constraints which impinge upon the individual.[4]

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Over the years, the thinking of Emery Castle and Warren Samuels has been influential in the development of my views. However, neither is to blame for the configuration these views have currently assumed. Let me acknowledge, without implication, that perceptive comments from Samuels, Harold Breimyer, Thomas Clevenger, Clyde Eastman, James R. Gray, Eliot Orton, James Taylor, seminar audiences at New Mexico State University and Oregon State University, and the *Journal's* anonymous reviewers have resulted in substantial improvements to earlier drafts of this article.

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[1] Rothschild, in his excellent introduction to [8], provides some insights into the reasons for the dominance of neoclassical models in modern micro-economics and the resulting neglect of the concept of power.

[2] Rothschild [8] reminds us that even the monopoly models of neoclassical theory, regarding monopoly as simply the absence of competition, provide a very incomplete concept of power in economics.

[3] The word "paradigm" is defined by Webster as being synonymous with "model." Here, "paradigm" is used because the construct presented is verbal, while "model" tends to denote to economists a mathematical construct.

This paradigm is derived and developed from that presented by Warren Samuels [9], who acknowledges his intellectual debt to Robert L. Hale and John R. Commons, among others.

[4] Already it can be seen that this paradigm is not incompatible with the neoclassical competitive model. In that model choice is also constrained. The difference is in the ethical implications attached to the constrained

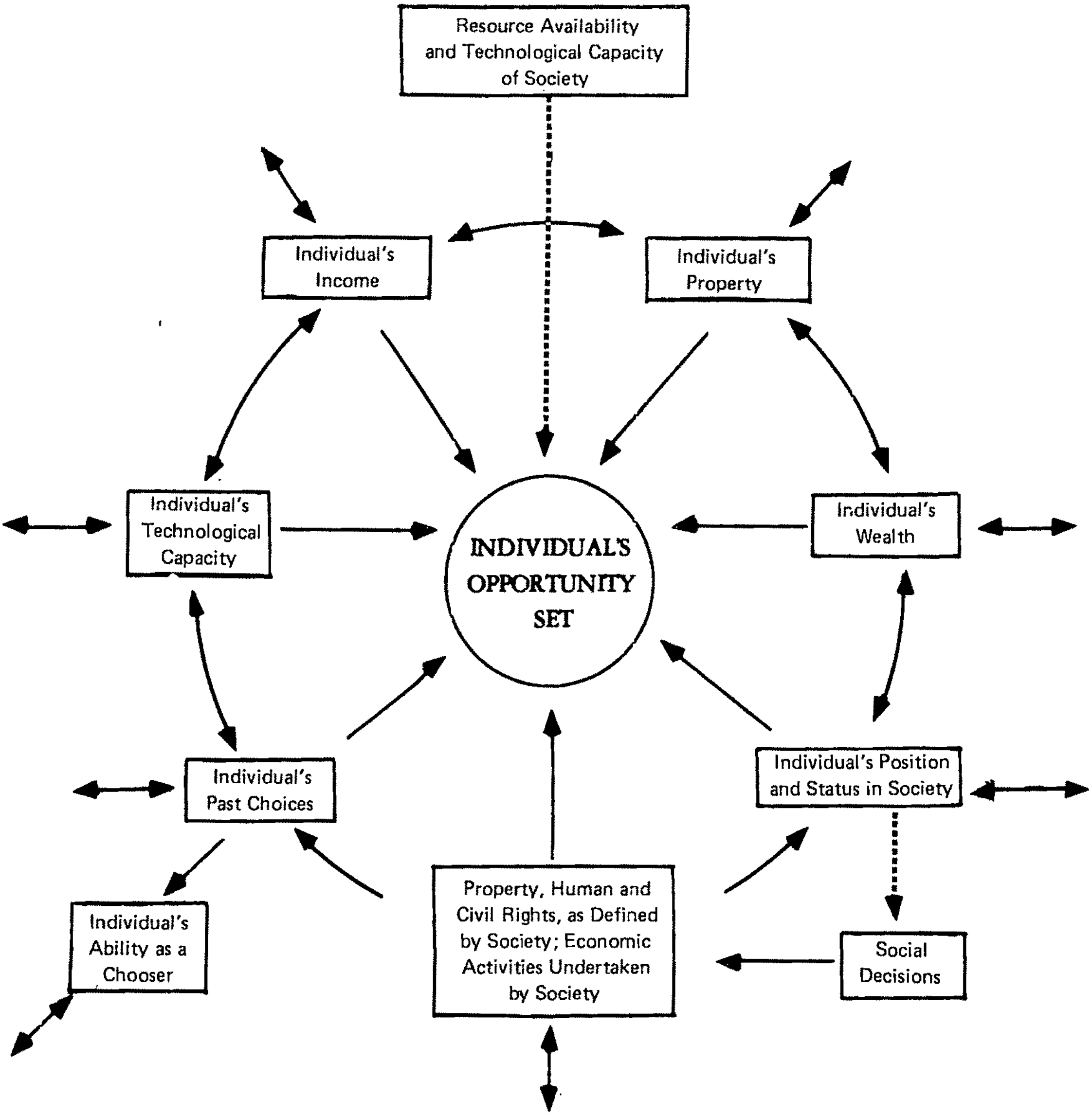
Resource Availability and Technological Capacity of Society
Individual's Income
Individual's Property
Individual's Technological Capacity
INDIVIDUAL'S OPPORTUNITY SET
Individual's Wealth
Individual's Past Choices
Individual's Position and Status in Society
Individual's Ability as a Chooser
Property, Human and Civil Rights, as Defined by Society; Economic Activities Undertaken by Society
Social Decisions

Figure 1. The determination of the individual's opportunity set at a given instant in time

Figure 1 is a diagrammatic presentation of the way in which one individual's opportunity set is determined at a given instant in time. Some of the forces which determine the opportunity set, and interactions among these forces, are shown. The resource availability and technological capacity of society help to determine the opportunity set of the society in aggregate and thus, indirectly, the individual's opportunity set. Relative to the opportunity set of his compatriots, the size of the individual's opportunity set is determined by the individual's technological capacity, income, property, wealth, and position and status in society, all of which interact, and also by the past choices that individual has made and the social choices society has made. His past choices are influenced by his ability as a chooser, and his past choices will influence his

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nature of choice. For example, Milton Friedman [4] seems to regard the constraints imposed in the market as somehow inoffensive or much less offensive than constraints imposed upon market behavior by non-market institutions. The former seem to be thought much less a limitation upon freedom than the latter. But, in the current paradigm, a constraint is a constraint is a constraint! Limitation of one's opportunity set because of a tight budget constraint constricts freedom as much as a similar degree of limitation by any non-market constraint.

technological capacity, income, property, wealth, position, and status. He may have a not insignificant influence on social decisions if he has technological capacities, income, property, wealth, position, and/or status beyond the ordinary.

Figure 1 is open-ended. Although the possibility exists that the individual may exert some influence on many of the variables which determine his opportunity set, these same variables are influenced, usually to a much greater extent, by the actions past and present of other individuals and institutions. The freedom of the individual to be effective as a chooser is thus constrained by many variables, none of which is completely responsive to his will and upon many of which he may have precious little influence.[5]

Samuels [9] defines *coercion* as the impact of the behavior and choices of others on the structure and array of one's opportunity set.[6] *Power* is defined here as the means or capacity to exercise choice and therefore with which to coerce. The individual's power is relative to the power of others; he whose opportunity set is less constrained has more power.[7] The interaction of one's power and the power of others operating through institutional mechanisms such as the market and the political and legal systems is the basis for the structure of mutual coercion within which prices, resource allocation, and income distribution are determined, under conditions of aggregate scarcity and uncertainty.[8] If the distribution of power, broadly defined, is allowed to vary, resource allocation will change, prices will change, and the empirical specification of what is efficient will change.[9]

Conceiving the economy as a system of mutual coercion, it becomes impossible to avoid the moral dilemmas which confront anybody involved in the public sector or in social decision making. If an action taken in any public agency tends to increase the power of some people while reducing that of others (i.e., to make some people better off and others worse off), its distributional consequences cannot be attributed to some inevitable and inexorable economic law. Rather, these consequences are the result of a decision of which that agency should be conscious and for which it must take responsibility.

Information

Having defined the economy as a system of mutual coercion based on power, it is now appropriate to consider the role of researchers, teachers, and extension workers as creators and disseminators of information, mostly supported by public funds. Information is defined by Webster as new knowledge and intelligence. The provision of information changes the probabilities ascribed to various outcomes and may even suggest new outcomes previously unimagined with probabilities of their own.[10] As such, information assists the chooser to make choices. The provision of information is an activity which makes some choice decisions more likely and others less likely than they would have been in the absence of that information.

While information may sometimes increase the technological capacity and resource availability of society in aggregate, information almost always tends to enlarge the opportunity sets of some while diminishing those of others. Information, then, changes the relative power of individuals. It may do this in several ways.

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[5] Determination of the individual's opportunity set has been discussed for a single instant in time. Yet, the basic elements of a dynamic model are present in the impact of the past choices of the individual and others upon the size of his present opportunity set. The choices he and others make now will influence his opportunity set in the next time period. Similarly, uncertainty may be introduced by recognition of the uncertainty of nature and the limited knowledge the individual has about the total economic system and thus the ramifications of the decisions he and others make. The individual may be unaware of the complete scope of his opportunity set and will most likely be unaware of the choices others are making.

[6] The term "coercion" is not intended to be pejorative. As Paul Samuelson notes, "the price system is, and ought to be, a method of coercion" [10, p. 1415].

[7] The definition of power used here is very general. The concept is not confined to the active and deliberate exercise of power. While from time to time throughout history powerful individuals and groups have acted rapaciously, conspiring to benefit themselves with little concern for those made miserable by their actions, the concept of economic power need not always evoke that kind of image. Power can be exerted passively, nonmalevolently, and even unintentionally. The rich may have disproportionate influence simply because they have greater effective demand. The poor may be uninfluential simply because they own little that is a cost to others.

[8] The process of mutual coercion should not be perceived as necessarily a zero-sum game. Given the possibility of growth, the outcome of this process of mutual coercion will influence the rate of growth, the direction of growth, and the distribution of the fruits of growth.

[9] What, then, is the normative significance of a supply curve, a demand curve, a price? Very little, I suggest, since all of these things are very largely dependent on the structure of power within an economy, and the structure of power can be changed by political action as well as by what we have come to think of as economic changes. Economic data such as prices and supply and demand curves can be used in a normative context only if the current structure of power is assumed optimal.

[10] Into this latter context falls the type of information which presents a new way to do things, that is, new technology.

Information may increase the power of its beneficiary by making institutional changes to his benefit more likely through its impact on the social decision process and by increasing his technological capacity or ability as a chooser. Similarly, information may reduce the power of its victim by making institutional change to his detriment more likely and by increasing the technological capacities, or abilities as choosers, of others relative to his, so rendering his capacity and ability less valuable.

The technological capacity and decision making ability of the individual interact with the other variables which determine the constraints on the individual's opportunity set (Fig. 1) and, therefore, his power. Where information is available but expensive, those with greater incomes and/or wealth will have more access to it. Information which will increase efficiency in the production of certain commodities (or provision of certain services) is applied at the will of those who control the processes of production, as owners or managers of the means of production. Information which tends to encourage institutional change through its impact on social decision making will tend to be used most effectively by those whose position in society gives them more influence in social decision making. Each rational individual will use that information which is helpful to his cause and ignore or, more likely, attempt to impede the flow and cast doubt upon the veracity of information which is unhelpful.

It is into this context that researchers, teachers, and extension workers, as providers and disseminators of information, are thrust. Willingly or unwillingly, the purveyor of information is cast into the role of an active modifier of power relationships. This being so, it behooves him to consider carefully which kinds of power modifications are consistent with his personal morality, his professional ethics, and the social function of his host institution.

Academic Responsibility

The remainder of this paper is devoted to discussion of the role of those generators and purveyors of information who work in academic institutions and public agencies. The scientific ethic is examined in order to evaluate its adequacy for scientists who are employees and servants of the public.

Positivism and scientific objectivity are ethical values which are highly regarded by scientists. *Positivism* in research simply refers to the gathering and presentation of information about matters of fact. Popper [7] has defined *scientific objectivity* as consisting of the freedom and responsibility of the researcher to pose refutable hypotheses, to test the hypotheses with relevant evidence, and to state the results in an unambiguous fashion accessible to any interested person. The scientist who is scrupulously faithful to these procedures will do objective work, and the scientist who is not will be found out by his peers through a process of evaluation and replication of his work. Substantial problems exist in attaining scientific objectivity in the social sciences. Those interested are referred to Castle [2]. For now, suffice it to say that positivism and scientific objectivity, while difficult to attain, are both valid concepts. Scientific objectivity is a laudable ethical value for scientists, and positivism is appropriate to certain kinds of tasks.

Neither positivism nor scientific objectivity can assure *scientific neutrality*. The notion of scientific neutrality seems to enjoy some currency among researchers. The concept is nebulous and difficult to define, but includes several attributes, some of which are thought desirable by some, if not all, academic social scientists. One observes within the discipline of agricultural economics a written and oral tradition which attempts to differentiate the scholar from the partisan, the advocate, the promoter, and even the consultant. The scholar ought not attempt to modify the world in the way the others may. The scholar, in this formulation, should not promote particular value systems or particular solutions to problems, for fear that his advocacy will compromise his search for truth. The broad constellation of values supporting these views is herein called scientific neutrality.

Two of the major concepts in the constellation called scientific neutrality are identified and evaluated: value neutrality and neutrality of impact.

Value neutrality is often said to be a commendable characteristic in researchers. The value neutral scholar presumably is one who either has no values (save for a compulsion to seek truth) or, somewhat more credibly, is able to avoid the intrusion of his values into his scholarly work.

Clearly, value neutrality is a relative concept. It is the unobtrusiveness of the author's values which distinguishes scholarly writing from pamphleteering. Scholars should avoid the pretension of a total value neutrality which is unattainable by humans; in scientific reporting, it may often be appropriate for the author to state openly those values he holds relevant to the research at hand. The most scrupulous adherent of value neutral scholarship will reveal his values in his choice of topics to research and in his choice of variables to be examined, since no one can examine all variables in a system. This is not necessarily incriminating. It is argued below that a deliberate and systematic application of particular values to those tasks is desirable and necessary. Further, Castle [2] makes it clear that the performance of objective research does not rely upon the employment of completely value neutral scholars to perform it.

The notion of scientific neutrality seems also to include something which is here called *neutrality of impact,* which could be defined as a belief that positive and objective scholarship is or should be neutral with respect to the relative well-being of individuals or interest groups. Stated more directly, scholarly work should not take sides, deliberately or unintentionally, in situations where different parties have conflicting or competing interests. It is doubtful if many scientists wholly believe in neutrality of impact, as defined above. Yet, in several contexts, some scientists appear to place at least some faith in the notion. Some of the manifestations of that faith are as follows:

(a) The refusal of some scientists to consider the social consequences of their research.
(b) The confusion that exists with respect to the place of recommendations in scientific reporting. Some scholars appear to believe that any research study can achieve neutrality of impact simply by stopping short of explicit recommendations.
(c) The willingness of some economists to perform efficiency analyses, ignoring questions of distribution. Somehow, these economists seem to think that research on efficiency is both positive and impact neutral, while consideration of the distribution of income is neither.

None of these notions is valid. The scholarly provision of information modifies power relationships and the outcome of the process of mutual coercion and thus has social consequences. Those empowered (by ability, technological capacity, income, wealth, ownership, control, or position) to make decisions will do so, using the new information as a guide to those decisions which will be to their best advantage. This will occur, whether or not the scholarly report includes specific recommendations. In the case of efficiency analyses, it should be sufficient to point out that such analyses are normative rather than positive and are in no way neutral in their impact on outcomes. The choice to concentrate upon efficiency to the exclusion of income distribution, or vice versa, represents a choice between alternative normative values as to what is important.

The concept of neutrality of impact is insupportable. Scholars would be well advised to recognize clearly and explicitly the impact the provision of information has on the process of mutual coercion and its outcome. Such recognition is a prerequisite for development of an adequate ethic to guide the activities of publicly employed and supported scholars.

Obviously, positivism and scientific objectivity cannot assure neutrality of impact. Indeed, positivism and scientific objectivity are consistent with *impact distortion.* Impact distortion is defined, in the context of the scholarly provision of information, as the provision of more complete information about some aspects of a choice situation than others. Such a process may distort outcomes from what they would be if complete information were provided.[11] The following example demonstrates the consistency between scientific objectivity and impact distortion. It is possible to do completely objective work in evaluating particular benefits of a proposal without evaluating all of its costs. And, if that is the input made by the scientific community, that proposal is more likely to be approved: more likely than if all its possible effects had been examined with equal competence and diligence or if none had been carefully studied!

Not only is neutrality of impact impossible to achieve (except in the trivial case where information is ignored by all); there is no good reason to consider its achievement desirable, just as there is no good reason to believe the current distribution of power and its resultant social and economic outcome optimal. Further, impact neutrality is clearly undesirable in applied research, since its achievement would logically imply ineffectiveness and lack of applicability and/or application. However, it is reasonable to insist that impact distortion be avoided by scholars and their host institutions to the greatest extent possible. If the provision of information affects outcomes, then the academic world ought to make it its business to provide the most complete information possible about all aspects of any choice problem.

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[11] Impact distortion is not the antonym of neutrality of impact. In the total absence of impact distortion, impact neutrality will still not be achieved.

The economist as humble technician?

Nutter [6, p. 156] observes that many economists seem to believe that by restricting their study to matters of economic efficiency and growth they can become more scientific. But he warns that economic issues cannot be purged of moral content. He poses for us quite starkly the issue of whether the economist is more appropriately a humble technician or a moral philosopher.

The role of the humble technician, using his skills in the services of the highest bidder (whether the bidding takes place through market, political, or administrative mechanisms), may seem to have much to recommend it. The scholar may seem best equipped to generate and disseminate information without any particular concern for the question of in whose services, and for what purposes, that information will be used. Similarly, the humble technician skilled in working with metal may use that skill to make steam engines or gas ovens depending upon the desires of the highest bidder for his services. But therein lies the problem with this approach![12]

It is clear that the humble technician approach does not relieve the scholar of any of the moral responsibilities thrust upon him by the non-neutrality of the impact of his work. The humble technician role consists merely of the scientist substituting the values of his master for his own. At best, he substitutes one big moral decision for many smaller ones. At worst, he may find his position totally untenable, should the morality or professional ethics of his master conflict severely with his own.[13]

Bringing it all back home

Occasionally it is charged that impact distortion is prevalent in research related to agriculture. The book *Hard Tomatoes, Hard Times* [5] has recently generated much publicity for this charge. Specifically, it is charged that the land grant colleges and the research and information dissemination arms of the USDA have chosen to propagate technologies which are most readily applicable to large enterprises in agriculture, thereby increasing the power and economic welfare of owners of large enterprises while diminishing the power and economic welfare of owners of small enterprises, consumers, and agricultural labor.[14] In this book [5] the recommendation is made that the "USDA-land grant complex" devote more of its efforts and resources to generating the kinds of technology and social science input which would be of more benefit to small producers, agricultural laborers, and consumers, and therefore might help to shift power relationships in their direction.

The work of Schmitz and Seckler [11] examining the economic impact of the development of a mechanical tomato harvester is of interest in this context. First, it offers some support for the suggestion that impact distortion is not uncommon in agricultural research. The land grant colleges of California contributed to a technological advance which increased the power and economic welfare of tomato growers and consumers while reducing the power and welfare of itinerant agricultural laborers, a group whose power and economic status was already low. Second, the Schmitz-Seckler study is itself a pioneering example of research which attempts to avoid impact distortion by making a comprehensive evaluation of the economic impacts of, in this case, a technological innovation. Schmitz and Seckler provide information relevant to both private decisions on adoption of technology and social decisions as to appropriate treatment of the technologically displaced.

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[12] In his remarkable book, Albert Speer [12], the humble technician of the Third Reich, whose immense skills in industrial organization played a large part in the amazing longevity of that regime during the Second World War, provides considerable insight into the nature and dangers of the humble technician role.

[13] While the responsibilities of the scientist working in private enterprise differ in some ways from those of the scientist working in the public sector, the humble technician role is adequate for neither.

[14] This is not the place for a complete evaluation of *Hard Tomatoes, Hard Times*. However, it seems likely that, in aggregate, publicly sponsored agricultural research efforts have diminished the power of agricultural laborers and owners of small production units. The situation with respect to consumers is much more complex. It seems that agricultural research has been of substantial net benefit to consumers, although consumers may harbor reasonable concerns as to whether research which tends to increase concentration in certain industries and research which encourages the use of some chemicals as production inputs or preservatives is wholly to their benefit.

A minimal professional ethic for publicly supported social scientists would demand both scientific objectivity and a conscious effort to minimize impact distortion. The individual scholar should, as much as the limits of his human energy and competence allow, seek to examine and report all the various effects and implications of that which he is studying. His host institution, having at its command far greater intellectual and financial resources than any one scholar, ought purposefully to avoid impact distortion in its approval, funding, and administration of the research its scholars perform. For example, funding of a project to develop labor saving technology ought to be accompanied by funding of a project to evaluate all its potential impacts and funding of a project to help find new opportunities for the labor displaced, or to design institutions that allow displaced labor to obtain compensation and possibly to gain some of the benefits from technological progress.[15] The work of Schmitz and Seckler [11] and Ayer and Schuh [1], while admirable contributions by pairs of individual scholars, is not an adequate institutional response to the need to avoid impact distortion. It is *ex post* and isolated when it ought to be pervasive and both *ex ante* and *ex post*.

In addition to research approval and funding and administration policies that seek deliberately to avoid impact distortion, public institutions of research and scholarship have another weapon at their disposal, a weapon which is time honored in principle if not always in practice. Such institutions should actively encourage a diversity of scholarly output by gathering together competent scholars of diverse interests, with diverse intellectual approaches and diverse ideologies, giving them support and providing shelter as necessary when the ideas of individual scholars offend powerful groups within and without the institution. This kind of diversity will go a long way toward removing impact distortion from scholarly output in the aggregate.

It must be admitted that complete elimination of impact distortion, if that were possible, would guarantee neither social efficiency nor equity.[16] While a conscious effort to avoid impact distortion is in that sense no panacea, it remains an appropriate and even essential goal of scholars and their host institutions working for the public purpose.

Concluding Comments

It has been seen that the economic welfare of individuals and groups is determined in a process of mutual coercion. The provision of effective information modifies individual and social choices and hence power relationships and the outcome of the process of mutual coercion. While scientific objectivity is a desirable characteristic of research, it cannot assure that the impact of information produced by scholarly activity on power relationships is neutral. Not only that, but positivism and scientific objectivity are consistent with actual impact distortion. In such a context the scholar is faced with serious moral issues which cannot be avoided by retreat into the humble technician role.

Individual scholars and their host institutions ought purposefully to avoid impact distortion in the provision and dissemination of information (i.e., in research, teaching, and extension). Host institutions should do this through project approval, funding and administration procedures which actively discourage impact distortion, and the gathering, encouragement, and shelter of scholars with diverse interests, intellectual approaches, and ideologies.

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[15] Suggestions such as this may logically imply expansion of some kinds of research in public institutions, but also a contraction of other kinds of research. It may be necessary for public institutions occasionally to reject offers of funds from outside sources where (1) these funds are designated for research which would result in impact distortion, (2) some publicly supported scholars and facilities are used along with the private funds, and (3) the institution is unable to provide funding for additional research to eliminate the impact distortion, or, worse, is forbidden to do so as a condition of acceptance of the funds from private sources.

[16] If the total social costs of some innovation exceed its social benefits, but those who are its beneficiaries are empowered (perhaps by virtue of their position as owners or managers in the private sector) to implement that innovation, then it will be implemented. The uses to which information is put depend on current power relationships.

However, information also serves as an input in the modification of power relationships through the social decision process. The provision of information, widely publicized, about injuries to the relatively powerless and methods of mitigating those injuries may result in the mobilization of latent social and political support which helps redress the imbalance. The decade of civil rights activism, culminating in the significant legislation of the 1960's, is one example.

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Competitive Demand Structures under Risk in Agricultural Linear Programming Models*

P. B. R. HAZELL AND P. L. SCANDIZZO

A method is presented for solving agricultural sector models under risk to obtain perfectly competitive levels of outputs and prices in all product markets when producers behave according to an *E, V* decision criterion. The nature of market equilibrium behavior is considerably more complicated under risk than in a deterministic setting. This presents difficulties in designing models which will always provide meaningful economic answers. These difficulties are overcome by stipulating conditions under which the proposed model is applicable. The resultant model is a quadratic programming problem, and linearization techniques are suggested which enable solutions to be obtained through conventional linear programming computer codes.

Key words: **agricultural sector models; competitive markets; risk; linear programming.**

LINEAR PROGRAMMING MODELS are gaining increasing acceptance as tools for the sector analysis of agricultural supply response and agricultural investment programs. For many purposes it is desirable that such models provide the perfect competition solution to all product markets when both prices and quantities are endogenous. Samuelson [14] provided the basic methodology for achieving this in the deterministic case by utilizing the sum of consumers' and producers' surplus (net social product) as the model maximand. He developed this result in the context of spatial equilibrium models, and Takayama and Judge [17, 18] further developed this objective function to obtain a quadratic programming formulation for multiproduct models. Duloy and Norton [4, 5] subsequently applied the method to agricultural sector models using linear programming approximations.

The purpose of this paper is to provide a modification of the Duloy-Norton method when production is risky and individual farmers maximize *E, V* utility instead of expected profits. Neglect of such risk averse behavior can lead to important overstatements of the supply response of high risk enterprises, as well as overestimation of the returns to investment programs.

Since there are important interdependencies in the risk case between the way farmers behave and the nature of market equilibrium [8, 21], it will be necessary to explore both the micro and macro aspects of the model. The micro-macro aspects of the deterministic model are first reviewed, and then the implications of introducing risk are explored.

The Deterministic Model

The deterministic model is premised on the assumption that individual farmers are profit maximizers and that they compete in a perfectly competitive way. The latter assumption implies in particular that farmers plan on the basis of constant anticipated prices.

Define $\hat{p}$ = an $n \times 1$ vector of anticipated product prices,
c = an $n \times 1$ vector of unit costs,
x = an $n \times 1$ vector of enterprise levels,
M = an $n \times n$ diagonal matrix of enterprise yields with jth diagonal entry m_j,

and

$y = Mx$ is the $n \times 1$ vector of total outputs.

Then the objective function for an individual farm problem is

$$\text{(1)} \qquad \text{Max}\, \pi = \hat{p}'y - c'x,$$

and this is to be maximized over some set of constraints which are usually specified to be linear.

If the product markets attain an equilib-

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rium, then regardless of the way in which the anticipated prices $\hat{p}$ are formed over time, the equilibrium is unique. Furthermore, the market equilibrium prices and outputs occur at the points where the demand and implicit model supply functions intersect. This fact provides the basis of the solution procedure.

Let X, Y, C, and W be some appropriate aggregates[1] of the individual farm x, y, c, and M matrices, and P be the vector of unknown market prices. Then assuming the linear demand structure

$$(2) \qquad P = A - BY,$$

the Duloy-Norton aggregate model objective function is

$$(3) \; \text{Max}\, \Pi = X'W\,(A - 0.5\,BWX) - C'X$$

where it is understood that $Y = WX$.

The term $X'W\,(A - 0.5\,BWX)$ is the sum of areas under the product demand functions. For example, in the single product case this would be

$$\int_0^y (a - by)\,dy = y(a - 0.5by)$$
$$= wx\,(a - 0.5bwx).$$

The term $C'X$ is total production costs, or equivalently, the sum of areas under the product supply functions. Consequently, the difference between these two terms is the sum of producers' and consumers' surplus over all markets, and this reaches its maximum at the required intersections of supply and demand functions.

Introduction of Risk

The basic source of risk to be introduced is confined to yields. Thus the vector of products for an individual farm now becomes $y = Nx$ where N is an $n \times n$ diagonal matrix of stochastic yields with jth diagonal element ϵ_j.

Stochastic yields imply stochastic supply functions and hence lead to stochastic market prices, P. It is assumed, however, that input costs and the market demand structure remain nonstochastic and that the farm linear programming constraints are not effected. The latter assumption can easily be relaxed, since several techniques are available to handle stochastic constraints that do not effect the farm model objective functions [2, 11, 13].

It is further assumed that the individual farmers are risk averse and that their behavior conforms to a single period E, V specification [9, 10, 15]. Consequently, the individual farm model objective function each year is

$$(4) \qquad \underset{x}{\text{Max}}\; u = E(P'y) - c'x - \phi\, V(p'y)$$

where E and V denote, respectively, the expectation and variance operators, and ϕ is a risk aversion coefficient.

To enumerate (4) more precisely, it is necessary to make explicit assumptions about the nature of farmers' subjective anticipations. These in part depend on the nature of perfect competition under risk.

Perfect Competition Under Risk

As a natural generalization of the deterministic concept of perfect competition, it is assumed that farmers continue to expect that their outputs do not have any effect on the market. A set of behavioral anticipations which are consistent with this for all j are the following:

A1 $E(\epsilon_j) = m_j$

A2 $V(\epsilon_j) = \sigma_{\epsilon_j}{}^2$

A3 $E(P_j) = \hat{p}_j$

A4 $V(P_j) = \sigma_{p_j}{}^2$

A5 $\text{Cov}(P_iP_j) = \sigma_{p_{ij}}$; $\text{Cov}(\epsilon_i\epsilon_j)$
$= \sigma_{\epsilon_{ij}}$, all $i \neq j$

A6 $\text{Cov}(P_jy_i) = x_i\,\text{Cov}(P_j\epsilon_i) = 0$, all i,

where all operators are now subjective expectations and which may differ from the real world parameters. Assumption A3 states that farmers expect a constant mean price for each product, and by making the variance homoskedastic (A4) and the covariances between prices and outputs zero (A6), this implies that there is no expected relationship between the output of the individual farm and the market.

It is important to note that these are behavioral assumptions; it is not required that the farmer anticipate the true state of affairs. Market behavior is in part a reflection of what farmers anticipate, but this is basically no different from the deterministic case where, in the short run, the farmers' expectation of prices $\hat{p}$ can differ from the vector of market clearing prices P.

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[1] Aggregation should be exact to avoid biased results in the sector model. The usual approach to this problem is through appropriate classification of farms into homogenous groups [3, 16].

Given the above set of assumptions, the components of (4) can be enumerated as follows.

$E(P'y) = \hat{p}'Mx$ where $M = E(N)$

$V(P'y) = x'\Omega x$ where Ω is an n x n covariance matrix of activity revenues with diagonal elements

$$\begin{aligned}\omega_{jj} &= V(P_j\epsilon_j)\\ &= E(P_j^2\,\epsilon_j^2) - \hat{p}_j^2\,m_j^2\\ &= E(P_j^2)\,E(\epsilon_j^2) - \hat{p}_j^2\,m_j^2\\ &= \sigma_{p_j}^2\,E(\epsilon_j^2) + \hat{p}_j^2\,\sigma_{\epsilon_j}^2\end{aligned}$$

and off-diagonal elements

$$\begin{aligned}\omega_{ij} &= \mathrm{Cov}(P_i\epsilon_i,\, P_j\epsilon_j)\\ &= E(P_iP_j\epsilon_i\epsilon_j) - E(P_i\epsilon_i)\,E(P_j\epsilon_j)\\ &= E(P_iP_j)\,E(\epsilon_i\epsilon_j) - \hat{p}_i\hat{p}_j\,m_im_j\\ &= E(P_iP_j)\,[E(\epsilon_i\epsilon_j) - m_im_j]\\ &\qquad + m_im_j\,[E(P_iP_j) - \hat{p}_i\hat{p}_j]\\ &= [\sigma_{p_{ij}} + \hat{p}_i\hat{p}_j]\,\sigma_{\epsilon_{ij}}\\ &\qquad + m_im_j\,\sigma_{p_{ij}}.\end{aligned}$$

The farm problem objective function is then

$$(5)\qquad \underset{x}{\mathrm{Max}}\, u = \hat{p}'Mx - c'x - \phi x'\Omega x.$$

Obviously, alternative assumptions to A1 through A6 are possible. However, providing A1, A3, and A6 are retained, then the only effect of changing the assumptions is on the elements of Ω. This will effect the market behavior and the estimation of Ω in a quantitative way, but does not deter the development of qualitative results about farm behavior.

Let the linear programming constraints for the farm model be denoted by $Dx \leqslant b$, then the Lagrangian function for maximizing (5) over this set is

$$(6)\quad L = \hat{p}'Mx - c'x - \phi x'\Omega x + v'(b - Dx)$$

where v is a vector of dual values. An optimal solution to the problem is then a saddle point, and necessary and sufficient conditions for any (x, v) to be this saddle point are obtainable from the Kuhn-Tucker conditions. The necessary conditions are

$$(7)\qquad \frac{\partial L}{\partial x} \leqslant 0, \frac{\partial L}{\partial v} \geqslant 0$$

$$(8)\qquad x\frac{\partial L}{\partial x} = 0,\; v\frac{\partial L}{\partial v} = 0.$$

Of these, the requirements in (8) are the complementary requirements that an activity cannot be active and at the same time have a non-zero opportunity cost, and a resource cannot be slack and at the same time have a non-zero dual value. Sufficient conditions for a saddle point can be derived but reduce to the requirement that Ω be a positive semidefinite matrix [18, p. 19].

Applying the necessary requirements in (7) to (6) gives

$$(9)\quad \frac{\partial L}{\partial x} = \hat{p}'M - c' - 2\phi x'\Omega - v'D \leqslant 0$$

$$(10)\qquad \frac{\partial L}{\partial v} = b - Dx \geqslant 0.$$

(10) is merely the feasibility requirement, but (9) contains the risk counterpart to the classical marginality rules for output determination in a deterministic firm. Taking the jth element of the vector $\frac{\partial L}{\partial x}$, rearranging terms, and dividing by m_j,

$$(11)\quad \hat{p}_j \leqslant \frac{1}{m_j}[\sum_k v_k\,d_{kj} + c_j + 2\phi \sum_i \omega_{ji}\,x_i]$$

This states that for each product the expected marginal cost per unit of output must be equal to or greater than the expected price. The expected marginal cost comprises expected own marginal cost c_j/m_j plus a marginal risk factor $\frac{\phi}{m_j}\frac{\partial V(P'y)}{\partial x_j} = \frac{1}{m_j}2\phi\sum_i \omega_{ji}\,x_i$, plus expected opportunity costs $\frac{1}{m_j}\sum_k v_k\,d_{kj}$ as reflected in the dual values of the resources used by that activity. This differs from the comparable requirements of a deterministic model primarily in that a risk term has been introduced. This is quite reasonable because the risk term is really nothing but a new cost, namely, the additional expected return demanded by farmers as compensation for taking risk. This is even clearer when farmers can participate in a crop insurance program, for then the risk term is the marginal premium a farmer would be willing to pay to insure against risk, i.e., a certainty equivalent cost.

This result is not new and is consistent with the results obtained for single product firms in economic analysis (e.g., see [12]). Further, the appearance of the risk factor as a marginal cost provides the rationale for the expectation that deterministic models overestimate the supply response of high risk crops. This is because $\Sigma_j\omega_{ji}x_i$ will then be positive, hence the marginal cost curve must lie above the marginal cost curve that would be obtained from a deterministic (or risk-neutral) model.

While (11) is a necessary condition, it is clear from duality theory that the condition will always be satisfied as an equality in an optimal solution for all activities which enter the basis [18, ch. 2]. Consequently, for all basic activities the risk counterpart to the price-equals-marginal-cost rule can be written as:

$$(12)\quad \hat{p}_j = \frac{1}{m_j}\Big[\sum_k v_k d_{kj} + c_j + 2\phi \sum_i \omega_{ji} x_i\Big].$$

The right hand side of (12) is then the short-run supply function for the farm as implicitly embedded in the programming model. This is a basic behavioral relationship and expresses the farmer's determination of x_j given his expectations about yields and prices. That is, $x_j = f(M, \hat{p}, \Omega)$, everything else constant. Multiplying by the mean yield m_j, a conditionally expected supply function is immediately obtained:

$$(13)\quad E(y_j|x_j) = m_j x_j = m_j f(M, \hat{p}, \Omega).$$

Since all the expectations involved are subjective anticipations, it is useful to denote (13) as the *anticipated* supply function for the farm to distinguish it from a true statistical relationship.

Market Equilibrium Under Risk

By summing the anticipated supply functions over all farms, an aggregate anticipated supply function can be obtained as a basic behavioral relationship in the market. Ignoring aggregation problems for now, the jth supply function can be written as

$$(14)\quad E(Y_j|X_j) = w_j X_j = w_j g(W, \rho, \Gamma)$$

where X_j, Y_j, W, $\hat{\rho}$, and Γ are suitable aggregates of x_j, y_j, M, $\hat{p}$, and Ω respectively, and w_j is the jth diagonal element of W.

Given X_j, actual supply is

$$(15)\quad Y_j|X_j = e_j X_j = e_j g(W, \hat{\rho}, \Gamma)$$

where e_j is a suitable aggregate of the farm ϵ_j's such that $E(e_j) = w_j$. Clearly, actual supply is stochastic with e_j and, furthermore, is of a specification in which the slope of the supply function is stochastic. Ignoring the unnecessary complication of a stochastic intercept term and assuming e_j to be bounded on some positive interval $e_m \leqslant e_j \leqslant e_x$, the market solution can be portrayed as in Figure 1.

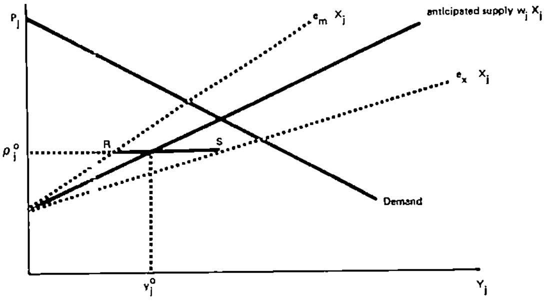

Figure 1

If W and Γ remain constant, the anticipated supply function is fixed, and aggregate anticipated supply is determined by $\hat{\rho}$. Thus for given $\hat{\rho}$ with $\hat{\rho} = \rho_j^o$, farmers will plan their farms so that aggregate expected output is Y_j^o. However, because yields are stochastic over the range e_m to e_x, actual supply can take on any value between R and S. More generally, the actual supply function can rotate around the anticipated supply function to any position contained in the funnel defined by $e_m X_j$ and $e_x X_j$. It follows that market price must always be stochastic and will fluctuate with both e_j as well as with X_j if the latter does not stabilize to some equilibrium amount. Further complications arise when W or Γ are not fixed, for then the whole 'supply funnel" may shift structurally over time.

The question now arises as to what is a perfectly competitive and equilibrium solution to the market, and since it is obviously not a point solution, what characteristics can usefully be derived with a mathematical programming model? The intuitive answer would be to view the market as stabilizing in its price distribution and to seek the perfectly competitive solution for expected price and output at the intersection of the demand and anticipated supply schedules. Unfortunately, while equilibrium is appropriately viewed in terms of a stabilizing price distribution, the properties of this distribution do depend on the way in which farmers form their expectations about $\hat{\rho}$, W, and Ω. That is, the equilibrium is interdependent with the adjustment mechanism. Further, only under certain conditions do the demand and anticipated supply schedules actually intersect at the equilibrium value of expected price. It is therefore necessary to explore these problems in greater depth.

To initiate the analysis, the following assumptions are made:

A7 W and Γ are fixed.

A8 X_j is a linear function in $\hat{p}_j$ of the form $X_j = \lambda \hat{p}_j$ where λ is some appropriate function of W and Γ and is therefore a constant by A7. That is, the response function for X_j in a programming model is being approximated by a straight line. Actual supply in the tth year is then $Y_{jt} = \lambda e_{jt} \hat{p}_{jt}$.

A9 Demand is linear and of the form $P_{jt} = a - bY_{jt}$.

A10 Farmers form their anticipated, or mean, price forecasts each year as a weighted average of past prices.[2] That is,

$$\hat{p}_{jt} = \sum_{i=1}^{m} \gamma_i P_{jt-i} \text{ and } \sum_{i=1}^{m} \gamma_i = 1. \tag{16}$$

Note that a naive cobweb formulation and the Nerlove type adaptive expectation models are special cases of (16), so that the formulation is quite general.

A11 $\mathrm{Cov}(e_{jt}, e_{jt-1}) = 0$, all t. That is, the yield of an individual activity is uncorrelated with itself over time.

Ignoring the jth subscript for convenience, it is evident that if the market clears each year, then market clearing price is

$$P_t = a - b\,\lambda e_t\,\hat{p}_t = a - b\,\lambda e_t \sum_{i=1}^{m} \gamma_i P_{t-i}. \tag{17}$$

Equilibrium can now be defined in terms of the convergent properties of P_t over time. There are a number of alternative properties to choose from [21], but basically all are variants of the concept of convergence in the probability density function of P_t and its various central moments. Consider first the convergence of expected price:

$$\begin{aligned} E(P_t) &= a - b\,\lambda\,E(e_t\,\hat{p}_t) \\ &= a - b\,\lambda\,w\,E(\hat{p}_t) \\ &= a - b\,\lambda\,w \sum_{i=1}^{m} \gamma_i E(P_{t-i}). \end{aligned} \tag{18}$$

This is an mth order difference equation, and if convergence occurs, has the particular solution

$$\lim_{t\to\infty} E(P_t) = \frac{a}{1 + b\,\lambda\,w}. \tag{19}$$

Further, it is the same for any choice of γ weights satisfying (16).

Solving now for the intersection price (P^*) of demand and anticipated supply ($Y_t | X_t = \lambda w_t\,\hat{p}_t$), $\frac{a}{b} - \frac{1}{b} P^* = \lambda\ w\ P^*$; hence $P^* = \frac{a}{1 + b\,\lambda\,w}$ which is identical to $\lim E(P_t)$.

Thus, under assumptions A7 through A11, the asymptotic expectation of market price is the same regardless of the specific price learning model, and, furthermore, corresponds to the desired intersection of the demand and anticipated supply functions. It is also clear from the derivation of anticipated supply that at this point $\lim E(P_t) = E(\text{marginal costs})$, which provides an acceptable equivalence to the equilibrium point of a competitive but deterministic market.

Turning now to other properties of the equilibrium, it can be shown that even under assumptions A7 through A11, the variance and probability density function of price *do not* converge to the same limits for alternative choices of the γ weights [8]. These properties of the equilibrium do depend on the way farmers form their price anticipations each year and consequently can only be enumerated through simulation type procedures given explicit assumptions about the behavior involved. A similar result pertains for the stochasticity of input decisions, and hence X_j.

The results for $E(P_t)$ are clearly quite useful, but what happens if any of the assumptions A7 through A11 are relaxed?

(a) If either A8 or A9 are relaxed to permit non-linearities, then $\lim E(P_t)$ usually becomes dependent on the γ weights in (16) and no longer corresponds to the intersection of demand and anticipated supply. Under these conditions the intersection price is only a linear approximation to the asymptotic expectation of price.

(b) Relaxation of A7 leads to a situation in which the slope of the supply function (λ) varies structurally over time, and the location of the anticipated supply function will no longer be fixed. However, if W and Γ converge,[3] then a stable equilibrium is attained with the above properties, and the only effect is on the speed of attaining the equilibrium. A similar result pertains when A10 is relaxed providing $\lim E(\hat{p}_t) = \lim E(P_t)$; otherwise approximations are again involved.

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[2] It is to be noted that an E, V decision specification only states which price and yield parameters are relevant each year; it does not state how anticipations about these parameters are formed over time.

[3] It is interesting to note that if assumptions A1 through A6 are a true description of competitive behavior, then Γ is unlikely to converge to its real statisti-

(c) A11 is only a simplifying assumption and can be relaxed to consider autocorrelated yields providing the stochastic residual of the process satisfies assumption A11. The main result is an increased complexity in the algebra.

The authors feel that assumptions A7 through A11 and the possible modifications stated above provide quite reasonable approximations to the real world and that the analytical results derived therefrom provide a reasonable description of market equilibrium behavior. On this assumption, any mathematical programming models that could provide the intersection solution for demand and anticipated supply would generate results that have a direct and relevant economic interpretation and that would be reasonably general with respect to the way in which farmers form their price and yield anticipations over time.[4] The task remains of providing a modification to the Duloy-Norton objective function that solves this problem in an aggregate model.

Solving for the Asymptotic Expectation of Price

X, Y, W, C, $\hat{p}$, and Γ have already been defined as aggregates of the farm x, y, M, c, $\hat{p}$ and Ω matrices. Also, let Φ be an aggregate of the farm risk parameters ϕ.

In forming these aggregates, there are definite problems that are closely related to the problem of establishing farm classification criteria for exact aggregation in quadratic models. This problem lies beyond the scope of this paper, and it is merely noted that the aggregate variables Γ and Φ must be chosen so that

$$\Phi\, X'\Gamma\, X = \sum_k \phi_k\, x'_k\, \Omega_k\, x_k$$

where k denotes the kth individual farm. Without this condition any possible covariance relationships between farms could be exploited in the aggregate model in seeking efficient diversification, and this would be inconsistent with assumed competitive behavior. Thus, for example, if all the farms were identical, a suitable choice of the aggregate variables would be $\Phi = \frac{1}{k}\,\phi$ and $\Gamma = \Omega$ so that $\sum_k \phi_k\, x'_k\, \Omega_k\, x_k = K\,\phi\, x'\,\Omega\, x = K^2\,\Phi\, x'\,\Gamma\, x = \Phi\, X'\Gamma\, X$ where $X = K\, x = \sum_k x_k$.

Given the necessary aggregate variables and parameters, it is now possible to modify the Duloy-Norton objective function to obtain the solution corresponding to the intersection of demand and anticipated supply schedules. This modified function is

$$\text{(21)}\quad \operatorname{Max} U = X'W(A - 0.5BWX) - C'X - \Phi\, X'\Gamma X$$

where $X'W(A - 0.5\ BWX)$ is now the sum of expected areas under the demand curves and $C'X + \Phi\ X'\Gamma X$ is a revised sum of areas under the supply curves.

To verify that (21) gives the desired solution, form the Lagrangian function $L = X'W(A - 0.5\ BWX) - C'X - \Phi X'\Gamma X + v'(b - DX)$ where b and D denote the aggregate constraints and v is a vector of dual values. Apart from complementary requirements, the necessary Kuhn-Tucker conditions are:

$$\text{(22)}\quad \frac{\partial L}{\partial X} = WA - WBWX - C - 2\,\Phi\,\Gamma X - D'v \leqslant 0$$

and

$$\text{(23)}\quad \frac{\partial L}{\partial v} = b - DX \geqslant 0.$$

(23) is the feasibility requirement, and (22) can be rearranged as

$$\text{(24)}\quad (A - BWX) \leqslant W^{-1}\,[C + 2\Phi\,\Gamma X + D'v].$$

Now WX is the vector of anticipated supplies $E(Y|X)$, and $A - BWX$ is the corresponding vector of market prices. Further, the right-hand side of (24) is the sum of expected marginal cost curves over all farms [the jth component is the sum of the right hand sides of equations like (11)]. That is, it is the vector of aggregate anticipated supply functions. The inequality in (24) states that in aggregate, farmers must operate around some expected point on the anticipated supply functions which lie at or

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cal value, for there will almost certainly be non-zero correlations between individual farm outputs and market prices.

[4] Extension of the results for $E(P_t)$ to the multiproduct case are quite straightforward, but are too lengthy to report here.

above the intersections with demand. Clearly, by duality, optimality occurs at the intersection point for all non-zero activities in the solution, and then $A - BWX$ is the intersection price vector. However, conditions have already been established for this to be an approximation to the vector of asymptotically expected prices, and if these conditions are met, the perfectly competitive solution for $\lim E(P) = E$ (marginal costs) will have been obtained.

Linear Programming Approximations

The aggregate model with the objective function defined in (21) is a quadratic programming problem. Because of the large dimensions of any realistic sector model and the difficulties that still exist with quadratic programming computer codes, it is clearly desirable to linearize this problem.

Duloy and Norton [4, 5] have shown how the term $Y'(A - 0.5\ BY)$ where $Y = WX$ can be linearized. To illustrate their method, consider the simplest case when B is diagonal, implying that the product demands are independent. Then, letting V_j denote the area under the demand curve (the definite integral) from 0 to Y_j for the jth product, $Y'(A - 0.5\ BY) = \sum_{j=1}^{n} V_j$.

V_j is a quadratic, concave function when plotted against Y_j, and since the programming model is a maximization problem, V_j can be approximated by a series of linear steps using conventional linear programming computer codes. Duloy and Norton introduce additional activities, V_{ij}, $i = 1$ to k for each V_j; assign upper bounds, $V_{ij} \leqslant g_{ij}$ on Y_j over which interval V_{ij} applies; and assign a single value of V_j, say, d_{ij}, which is to approximate V_j over the interval $Y_j \leqslant g_{ij}$. They then suggest that the part of the programming problem involving Max $Y'(A - 0.5\ BY)$ with $Y = WX$ be replaced by the LP problem.

$$\text{Max} \sum_j \sum_{i=1}^{k} d_{ij} V_{ij} \tag{24}$$

such that

$$X_j m_j - \sum_i g_{ij} V_{ij} \geqslant 0, \qquad \text{all } j \tag{25}$$

$$\sum_i V_{ij} \leqslant 1, \qquad \text{all } j. \tag{26}$$

This method adds only two rows for each product, but permits inclusion of as many V_{ij} activities as desired to increase the accuracy of the approximation to any degree of precision.

The remaining quadratic term $\Phi X'TX$ can be linearized along the lines suggested by Thomas *et al.* [19]. However, the approach leads to large programming problems that must be solved with special separable LP algorithms and that do not necessarily yield a global optimum solution. Alternatively, if Γ is estimated on the basis of time series data, the mean absolute deviation (*mad*) method proposed by Hazell [7] can be used.

Let $r_{jt} = P_{jt} m_{jt}$ denote the tth observation, $t = 1$ to T, on the revenue of the jth activity X_j, and let $\bar{r}_j$ denote the sample mean revenue for the activity over the T years.[5] Then, following Hazell, the classical estimate of variance used in the programming model

$$\text{EST}(X'\Gamma X) = \sum_i \sum_j X_i X_j \left[\frac{1}{T-1} \sum_t (r_{jt} - \bar{r}_j)\,(r_{it} - \bar{r}_i) \right] \tag{27}$$

can be replaced by the less efficient, but more easily linearized estimator

$$\text{EST}\,(X'\Gamma X) = \Delta \left\{ \frac{1}{T} \sum_t \left| \sum_j (r_{jt} - \bar{r}_j)\, X_j \right| \right\}^2 \tag{28}$$

where

$\Delta = T\pi/2(T-1)$ and

$\pi =$ the mathematical constant.

By defining new variables $z_t \geqslant 0$, all t, which measure negative deviations in total revenue around the mean for the tth set of revenue outcomes [7], it follows that

$$2 \sum_t z_t = \sum_t \left| \sum_j (r_{jt} - \bar{r}_j)\, X_j \right| \qquad (= Z).$$

To obtain the estimated variance, it merely remains to approximate the square of Z using the Duloy and Norton method discussed above and then to multiply the resultant value of Z^2 by Δ/T^2. Define variables V_i, $i = 1$ to k, with upper bounds $V_i \leqslant g_i$, and assign values d_i to each V_i which approximate the value of Z^2 over

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[5] The raw data should first be analyzed for any trend and other systematic movements over time, and these components removed to obtain a random residual.

Table 1. Layout of tableau for the linearized problem

Constraint and Text Equation Numbers	Production Activities X_1	$X_2 \ldots\ldots X_n$	n Sets of Activities to Linearize Areas Under Demand Functions $V_{11} \ldots V_{1k}$	$V_{21} \ldots V_{2k} \ldots V_{n1} \ldots V_{nk}$	T Negative Deviation Counters $z_1 \ldots\ldots z_T$	Sum Negative Deviations Z	k Activities to Linearize Z^2 $V_1 \ldots\ldots V_k$	RHS
Objective Function (21), (24) and (29)	$-c_1$	$-c_2 \ldots\ldots -c_n$	$d_{11} \ldots d_{1k}$	$d_{21} \ldots d_{2k} \ldots d_{n1} \ldots d_{nk}$	$0 \ldots\ldots 0$	0	$-(\Phi\Delta/T^2)d_1 \ldots -(\Phi\Delta/T^2)d_k$	Maximize
n Commodity Balance Constraints (25)	m_1	$m_2 \ldots m_n$	$-g_{11} \ldots -g_{1k}$	$-g_{21} \ldots -g_{2k} \ldots -g_{n1} \ldots -g_{nk}$				≥ 0
n Convex Combination Constraints (26)			$1 \ldots 1$	$1 \ldots 1 \ldots 1 \ldots 1$				≤ 1
T Revenue Constraints Containing Sample Data (30)	$r_{11} - \bar{r}_1$ $\vdots$ $r_{1T} - \bar{r}_1$	$r_{21} - \bar{r}_2 \ldots r_{n1} - \bar{r}_n$ $\vdots$ $r_{2T} - \bar{r}_2 \ldots r_{nT} - \bar{r}_n$			$1 \ldots 1$			≥ 0
Z Identity (31)					$2 \ldots\ldots 2$	-1		$= 0$
Z^2 Balance (32)						1	$-g_1 \ldots\ldots -g_k$	≤ 0
Convex Combination (33)							$1 \ldots\ldots 1$	≤ 1
Resource Constraints	D Matrix							$\leq$ b vector

the interval $Z \leqslant g_i$. Then the problem of minimizing $X'TX$ can be approximated by:

$$\text{Min}(\Delta/T^2) \sum_{i=1}^{k} d_i V_i \tag{29}$$

such that

$$\sum_j (r_{jt} - \bar{r}_j)X_j + z_t \geqslant 0, \text{ all } t. \tag{30}$$

$$2 \sum_t z_t = Z \tag{31}$$

$$Z - \sum_i g_i V_i \leqslant 0 \tag{32}$$

$$\sum_i V_i \leqslant 1. \tag{33}$$

Results about the reliability of this approach compared to using (27) are available elsewhere [7, 20].

In order to show how all these approximations fit together, a complete LP tableau is formulated in Table 1 that approximates the solution to the original quadratic programming problem. If all the quadratic terms are approximated by k segments, the linearized problem adds an additional $k(n + 1) + T + 1$ activities and $2n + T + 3$ rows to the problem, but this is highly efficient computationally when solutions are obtained through a revised simplex algorithm.

Conclusions

In this paper a methodology has been developed for simulating, with an LP model, the market equilibrium of a perfectly competitive but risky agriculture in which producers behave according to an E, V decision criterion.[6] Such results are useful for comparative static analysis of policy problems, and, according to the degree of risk involved, should be more descriptive than existing models which ignore risk.

The development of this methodology has pinpointed a number of difficult issues with respect to both the design and implementation of aggregate risk models.

First, market equilibrium is considerably more complicated under risk than in a deterministic setting, with interactive effects between the way farmers form their anticipations about prices and yields and the properties of an equilibrium if attained. Consequently, it is difficult to design a general programming model which will always provide meaningful economic answers. In this paper the problem was resolved by specifying a set of plausible assumptions under which the proposed model is appropriate but with an obvious loss in generality.

Second, an aggregate model must be defined in terms of variables which are inherently difficult to measure. This is partly because they are based on individual farmer's utility functions and subjective expectations about stochastic variables and are therefore difficult to observe, but partly because they involve aggregation procedures which have not been adequately explored in the literature. The authors have overcome these problems in practice by using statistical estimates of the aggregate variables obtained from time series data. While such results have been seemingly useful, the variables used are at best proxies for their real counterparts, and the method leaves much to be desired as a research technique.

These problems ought to be explored more fully given the importance of risk to agricultural planners throughout the world.

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[6] The model can readily be adapted to handle situations in which alternative decision criteria are appropriate. For example, if producers behave according to an E, standard deviation criterion [1, 6], then the aggregate model maximand should be $\text{Max } U = X'W\ (A - 0.5\ BWX) - C'X - (X'TX)^{1/2}$. Mixtures of decision criteria are also possible, but an economic interpretation of the market results is then more complex.

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Supply Response and Marketing Strategies for Deciduous Crops*

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Recent surveys show large increases in Washington apple tree plantings. When these plantings come into production, prices received by growers are expected to be below production costs. A simulation model combining supply, demand, and random weather variables was used to compare future returns and production variables of present fresh-processing allocation policies with alternative policies. The discriminating monopolist policies produced higher discounted revenues, more stable prices, and greater production and tree numbers during the 1972–1981 period than present policies. Thus, the monopolist short-run increase in returns over the present policy was prevalent after accounting for supply response.

Key words: **apples; supply response; simulation; market allocation policies; deciduous tree crops; polynomial distributed lag models; random weather components.**

THE PRIMARY OBJECTIVE of this paper is to examine the future consequences of the present marketing policy and compare it with alternative marketing policies of Washington's apple industry. Production of Washington apples is expected to increase much faster than U. S. population because of the current large numbers of nonbearing trees. Plantings of Washington apples have proceeded at an unprecedented rate since the late 1960's [2]. The discriminating monopolist allocation policy between fresh and processing markets is one approach to improve grower returns. However, in the absence of restraints on production, initially higher returns received by growers should increase supplies and bring returns down to their initial level. This hypothesis was tested using a recursive simulation model.

A supply response function for the Washington apple industry was estimated by relating yearly tree plantings to past prices. A polynomial distributed lag model was used for this estimation. The simulation model first generates production for stochastic weather elements and the number of bearing trees. The alternative marketing policy then determines the amount of production going into the fresh and processing markets. Using demand relationships estimated by Scott [11], fresh and processing prices are estimated. Average price to growers is calculated and used as an input into the supply equation which generates new tree plantings. Other stochastic elements—quality of the fruit and the number of trees killed by severe freezes—enter the simulation to determine apple production in other geographic areas.

Simulation of future prices, tree numbers, and production offers an advantage over the deterministic models of being able to incorporate the effects of the stochastic components. In tree fruit production, weather has a substantial effect not only on current production but on tree numbers and the quality of fruit.

Supply Response

The first definitive supply response for deciduous tree fruits was French's 1956 study [5]. He allowed for production response to price in making projections of future Michigan and U.S. apple production and prices. Production was related to a simple weighted average of previous seasons' prices. In the 1962 study by French and Bressler [6], supply response to price was developed in terms of tree plantings and removals. Total production was derived by converting bearing trees into bearing acres and multiplying by the yield per acre. Yields per acre were extrapolated from a trend line based on historical data, thus ignoring the randomness of production due to weather.

In a 1969 study of the Florida citrus industry, Raulerson [10] accounted for the random characteristic of weather by including six randomly generated weather patterns and comparing the projections from each.

Recently Hamilton [7] estimated tree planting response functions for a number of California fruit crops. He hypothesized new trees planted as a function of future expected prices. Future expected price was a function of a finite number

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of past prices. This was estimated using a polynomial approximation of the unknown coefficients of past prices. Thus, the effect of each specified lagged price upon the plantings of new trees could be estimated. However, Hamilton stopped short of predicting future tree numbers or future supplies of fruit.

Perennial fruit crops represent a long-term commitment of land, labor, and capital to derive a future stream of net revenue. In the case of apples, the first four years represent extensive cash outflows with no revenue. Generally by the fifth year there is some harvestable production. Yield per tree gradually increases until about the twelfth year when potential production reaches a maximum. With proper cultural practices an apple tree's productive life can be maintained for at least an additional 30 to 40 years.

The following model for supply response incorporates these characteristics of perennial fruit trees. Total quantity produced is broken down into the identity, trees multiplied by yield,

$$Q_t = \sum_i Y_{i,t} A_{i,t} \tag{1}$$

where

Q_t = total production in year t,
$Y_{i,t}$ = yield per tree for trees in age group i of year t,

and

$A_{i,t}$ = number of trees in age group i of year t.

This identity accounts for differing yields according to age of trees. Yield is primarily a function of current and past weather conditions.[1]

$$Y_{it} = F\ (W_t, W_{t-1}, \ldots, W_{t-n}) \tag{2}$$

where $W_{t\text{-}\tau}$ = weather conditions influencing apple yield $t\text{-}\tau$ years past. Because the management and physiological links with weather are little known and of extreme complexity, yield is a random variable with a distribution based on past yields. Another useful identity breaks down the current number of trees into three components. Current number of trees in a given age group is equal to the number in that group the previous year minus the number killed by a freeze. Total number of trees in all age groups in year t is then equal to the sum of all age groups the previous year less the number killed by a freeze plus the net change in tree numbers due to economic factors (number of new plantings less removals due to natural attrition):

$$\sum_i A_{i,t} = \sum_i A_{i,t-1} + N_t - \sum_i L_{i,t-1} \tag{3}$$

where N_t is the net change in tree numbers exclusive of trees killed by a freeze, and $L_{i,t\text{-}1}$ is the number of trees killed by freeze. Since trees do not die immediately from a freeze, a lagged response for tree freezes is necessary. Thus,

$$L_{i,t} = h\ (F_{i,t}, F_{i,t-1}, F_{i,t-2}, \ldots, F_{i,t-\tau}) \qquad \tau = 0, \ldots, n \tag{4}$$

where

$F_{i,t-\tau}$ = a freeze $t - \tau$ years past.

The probability of different types of tree-killing freezes can be estimated from the past. In this study two different types of freezes were used: those occurring early in the winter killing primarily young trees and those occurring late in the winter killing older trees.

The net change in trees due to economic factors can then be related to new plantings less removals,

$$N_t = PL_t - R_t \tag{5}$$

where

PL_t = new plantings in year t
R_t = trees removed in year t.

These can be related to some function of expected future profitability,

$$PL_t = k\ [E\ (P)] \tag{6}$$

$$R_t = h\ [E\ (P)] \tag{7}$$

where

$E\ (P)$ = expectation of future profitability.

The data requirements for this type of supply response are the number of trees in each age category. These should be annual data. This data requirement is not met in the case of Washington apples. Available data are: (1) the total of bearing and nonbearing trees for the years 1954, 1959, 1964, and 1969 as reported in the *U. S. Census of Agriculture*, and (2) a sample of apple growers giving their total tree numbers, the number of bearing trees, and the number of new plantings less the number of removals for years since

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[1] Yield was generated for a mature tree equivalent. A tree equivalent represented the production from a 12-year-old tree or older. A five-year-old tree was considered one-eighth of a tree equivalent, a six-year-old tree, one-fourth of a tree equivalent, and so on.

1953.[2] These two sources of data were combined to obtain an estimate of the annual number of bearing and of nonbearing trees and yearly plantings less removals.

Due to data limitations, only the net change in trees could be estimated. Thus,[3]

$$N_t = g\,[E\,(P)]. \tag{8}$$

Actual death loss due to natural attrition excluding freezes was specified as a fixed percent for trees 20 years of age and older and as a different fixed percent for those trees less than 20 years of age:

$$d_{i,t} = c_i\, A_{i,t-1} \tag{9}$$

where

c_i = percentage of death loss due to natural attrition for age group i.

Therefore, new trees planted in year t were specified as[4]

$$PL_t = N_t + \sum_i d_{i,t}. \tag{10}$$

The only relationship that needs to be estimated empirically is that between net tree change and expectations of future profitability [equation (18)]. The remaining relationships are either identities or relationships that are related to weather in such a manner that the links of causality are too complex to be readily measured. In the simulation these are treated as exogenous random events.

A number of variables could be hypothesized as affecting growers' expectations about the future profitability of apples. Growers' gross returns, net returns per acre, or net returns per pound are three such variables. Common to these is the average price received by growers for their apples.[5] Furthermore, price is compatible with supply theory and is therefore used as the independent variable. Costs were accounted for by deflating the price series with the index of prices paid by farmers. Since future profitability is not an observable variable, it was hypothesized that expected future profitability is a function of recent past prices. In view of the longevity of the investment involved and the associated uncertainties, growers' behavior is assumed to be dependent on several years' prices. The length of the lag and the extent to which individual past years contribute to the explanation of N_t were left to statistical estimation procedures. The hypothesis expressed in the form of a finite distributed lag is

$$g[E\,(P)] = k + \sum_{\tau=0}^{T} \beta_\tau P_{t-\tau} \tag{11}$$

so that

$$N_t = k + \sum_{\tau=0}^{T} \beta_\tau P_{t-\tau} + U_t \tag{12}$$

where

$P_{t-\tau}$ = the season's average price received by Washington apple growers τ years past.

In applying ordinary least squares estimation techniques to equation (12) several difficulties are encountered. If the lag length is long, there may be too few degrees of freedom, and the lagged values of the dependent variable may be highly intercorrelated, thus yielding imprecise estimates [8]. Almon [1] initially stated that the lagged coefficients can be adequately approximated by a sufficiently low order polynomial. Malinvaud [9] and, more recently, Dhrymes [3] have proposed alternative derivations, thus avoiding the use of the Lagrange interpolation originally used by Almon. Let

$$\beta_\tau = \sum_{i=0}^{D} a_i \tau^i \tag{13}$$

where D is the order of the polynomial used to approximate β_τ. The finite distributed lag was constrained such that at some time in the past where $\tau = T$, the average price received by growers had no effect on the present rate of planting. Thus,

$$\beta_T = \sum_{i=0}^{D} T^i a_i = 0. \tag{14}$$

Solving for a_0,

$$a_0 = -\sum_{i=1}^{D} T^i a_i. \tag{15}$$

Substituting (15) into (13) yields

$$\beta_\tau = \sum_{i=1}^{D} a_i \tau^i - \sum_{i=1}^{D} T^i a_i. \tag{16}$$

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[2] While the results of this survey by the Statistical Reporting Service are not published, access to it was provided to the authors.

[3] This assumes the removal process due to economic factors to be the negative of the planting process.

[4] It was assumed that trees dying due to attrition were replaced within an orchard. This is an accepted practice in Washington, and it results in orchards with trees of varying ages.

[5] The price received by growers is commonly referred to as the packinghouse door price, hereafter called the *PHD* price.

Rearranging terms,

$$\beta_\tau = \sum_{i=1}^{D} (\tau^i - T^i)\, a_i. \tag{17}$$

Substituting (17) into (12) yields

$$N_t = k + \sum_{t=0}^{T} \sum_{i=1}^{D} (\tau^i - T^i)\, a_i P_{t-\tau}. \tag{18}$$

Reversing the order of the summation,

$$N_t = k + \sum_{i=1}^{D} a_i \sum_{\tau=0}^{T} (\tau^i - T^i)\, P_{t-\tau}. \tag{19}$$

Specifying T, the lag length, and D, the order of the polynomial, and transforming the initial data set gives

$$c_{i,t} = \sum_{\tau=0}^{T} (\tau^i - T^i)\, P_{t-\tau}. \tag{20}$$

Substituting (20) into (19), the unknown a_i can be estimated by ordinary least squares. Thus, the function estimated is

$$N_t = k + \sum_{i=1}^{D} a_i\, c_{i,t}. \tag{21}$$

β_τ can be found by direct substitution of the estimated a_i into (17).

Using data for the years 1953 through 1971, the constrained form of the polynomial lag was parametrically varied from $T = 3$ to $T = 10$. Also the degree of the polynomial, D, was reduced starting from a fourth-degree polynomial until the explanatory power of the independent variable was significantly reduced. The multiple correlation coefficients and their associated lag lengths for a second-degree polynomial lag model for the raw and deflated price series are recorded in Table 1.

The raw price series generally provided greater explanatory power than the deflated price series. Although growers may be more inclined to respond to raw prices *per se*, from a longer run point of view it is doubtful that growers can indefinitely ignore costs. Therefore the deflated price series was used in the subsequent simulation.

The lag length selected for the simulation model was eight years with $\beta_8 = 0$. This length had the highest R^2 value. The beta coefficients and the associated test statistics were:[6]

(22)

$$\begin{aligned} N_t = &- 2{,}791{,}640 + \underset{(2.718)}{50{,}487\, P_{t-0}} \\ &+ \underset{(4.525)}{77{,}142\, P_{t-1}} + \underset{(6.823)}{94{,}379\, P_{t-2}} \\ &+ \underset{(5.909)}{102{,}136\, P_{t-3}} + \underset{(6.035)}{100{,}594\, P_{t-4}} \\ &+ \underset{(6.046)}{89{,}574\, P_{t-5}} + \underset{(6.011)}{69{,}135\, P_{t-6}} \\ &+ \underset{(5.971)}{39{,}277\, P_{t-7}} \end{aligned}$$

$$R^2 = .696$$
$$\text{D.W.} = 1.912$$

All the estimated lagged equations consistently show first an increasing response and then a declining response to past prices over time. There are some plausible explanations for this. First, growers may have a certain psychological hesitancy to respond to present prices. Second, the availability of some inputs tempers planting decisions. Nursery stock must be planted one to two years prior to its sale to the orchardist.

Static microeconomic theory states that there exists an equilibrium when the cost of production is equal to the market price. As a check on the validity of the supply function, the equilibrium price was compared with the average cost of production. Setting N_t of equation (22) equal to zero where plantings equal replacements and solving for $P_{t-\tau}$ assuming all lagged prices are equal, the static equilibrium price is equal to 4.48 cents per pound. This compares favorably with Zuroske's study [14] where the average cost of production was 4.21 cents per pound and with Doran and Lange's study [4] where the estimated production cost was 4.73 cents per pound.

Demand

There have been a number of studies estimating the demand relationships for Washington apples. Scott's 1972 study [11] estimated demand equations for Washington's fresh and processing markets at the grower level. His work is recent, in agreement with economic theory, and conforms to the needs of the simulation model.[7]

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[6] The t values are expressed in parentheses and are calculated as follows: $\beta_\tau = \sum_{i=1}^{D} (\tau^i - T^i)\, a_i$.

Thus, where $D = 2$,

$$\begin{aligned} \text{Var}\, \beta_\tau &= \text{Var}\, [a_1 (\tau - T) + a_2 (\tau^2 - T^2)] \\ &= (\tau - T)^2\, \text{Var}\, a_1 + (\tau^2 - T^2)^2\, \text{Var}\, a_2 \\ &\quad + 2\, (\tau - T)\, (\tau^2 - T^2)\, \text{Cov}\, (a_1\, a_2). \end{aligned}$$

Hence $t = \beta_\tau / \sqrt{\text{Var}\, \beta_\tau}$.

[7] Scott estimated his equations by ordinary least squares. He assumed that the quantities sold fresh and for processing were not determined simultaneously. His assumptions seem valid since crop quality and not quantity has determined the proportion of the crop sold to the respective markets. Fresh prices to growers have been substantially higher than processing prices.

Table 1. Multiple correlation coefficients for constrained second order polynomial approximations[a]

Independent Variable	Lag Length 10	9	8	7	6	5	4	3
PHD price	.548	.608	.693	.718	.622	.462	.281	.096
PHD price ÷ index prices paid	.296	.529	.696	.624	.392	.198	.072	.012

[a] The dependent variable is net change in the number of trees in the state of Washington.

The demand equations used in the simulation model were:[8]

$$P_{P,PHD} = .3362 - \underset{**}{.4595}\, Q_p - \underset{**}{.3005}\, Q_t - \underset{**}{.04357}\, Q_{US} + .0011\, Y - .1457\, D + .0562\, X_t \qquad R^2 = .771$$

$$P_{F,PHD} = 29.8126 - \underset{**}{1.8821}\, Q_F - \underset{*}{.3345}\, Q_{US} + .00143\, Y - .17024\, D - \underset{**}{2.4462}\, X_6 \qquad R^2 = .879$$

where

$P_{P,PHD}$ = cents per pound received by Washington growers for apples sold in the processing market,

Q_P = pounds per capita of Washington processing apples sold,

Q_t = preharvest estimate of pounds per capita of total Washington apples produced,

Q_{US} = pounds per capita of total U. S. apples sold less pounds per capita of Washington apples sold,

Y = disposable income per capita

D = dummy variable representing the quality of the crop—0 equals normal, 1 equals poor crop years,

X_t = trend variable representing increased handling facilities for Washington's processing apples for year t,

$P_{F,PHD}$ = cents per pound received by Washington growers for apples sold in the fresh market,

Q_F = pounds per capita of Washington apples sold in the fresh market,

and

X_6 = packinghouse charges in cents per pound deflated by CPI.

Other U. S. Production

The quantity of U. S. apples produced (other than Washington's) was included in the simulation model because of its effect on the demand for Washington apples. Other U. S. production and plantings have increased at a modest but consistent rate since the early 1950's. Thus, other U. S. production was expressed as a function of time,[9]

$$Q_{US} = -114{,}475.00 + 60.62\, T$$
$$R^2 = .442$$

Standard error of the equation = 410.44

where

T = time expressed in years.

This equation was used to predict the mean value of other U. S. production. Given the mean and variance and assuming other U. S. production to be a normally distributed random variable, other U. S. production was determined stochastically in the simulation model.

Market Allocation Policies

Given total production, the quantities to be marketed in the fresh and processing market were determined by the following four market allocation policies.

Present allocation policy

The Washington apple industry uses its processing market as a salvage market for culled fruit. Over the past 10 years the industry has sent 80 percent of its fruit into the fresh market and the remaining 20 percent into the processing market. In years with exceptional amounts of poor quality fruit and/or large crops, the industry diverts up to 30 percent to processing. Likewise in years of good quality fruit and/or short crops, the industry may only divert 10 or 15 percent to processing. The industry does not sell fruit that is salable in the fresh market to the processing market despite the fact that Scott's [11] work has shown that such a policy could increase returns to the industry as a whole for a given year.

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[8] Significance of the coefficients at the .95 and .90 levels is indicated by * and **, respectively.

[9] Both coefficients are significant at the .99 level.

To analyze the future implications of the present allocation policy, certain rules were constructed for the simulation model. These rules are: (1) provided the random variable, yield, is within one standard deviation of its mean, the industry will divert 20 percent to the processing market regardless of crop quality; (2) in years of large crops 25 percent of the crop goes to processing unless quality is poor, in which case 30 percent goes to processing; (3) in years of small crops, 10 percent of the fruit goes to processing unless the quality is poor, in which case the diversion is 15 percent.

Price equalization policy

With the rules specified above in future years of large crops, the price in the fresh market can approach zero. Growers would not rationally make such a diversion. As an alternative, 80 percent was sent fresh and 20 percent to processing unless the fresh price was below the processing price. In this case, the industry allocates between markets such that the prices in the two markets are equal.

Discriminating monopolist policies

The simulation model used two discriminating monopolist policies. The first allocated annual production between fresh and processing such that marginal revenues were equated. The second allocated production among three markets: the fresh, the processing, and the dump. The dump was a throwaway market whose marginal revenue was —0.5 cents per pound.[10] The marginal revenues were equated in the fresh and processing market if they were above —0.5 cents per pound. When they were below —0.5 cents per pound, production was diverted to the dump until marginal revenues in all three markets were equated.

The simulation model

The supply, demand, and weather components were combined with a market allocation policy in the simulation model. Each market policy was implemented over a time horizon of 10 years. Since the simulation model was stochastic, each market policy was run over the 10-year horizon 30 times. The mean and variance for the prices and quantities in the fresh and processing markets along with total revenue, total production, the number of trees planted, and the total number of trees from the 30 runs were calculated.. The four policies were evaluated by the output characteristics.

The model first generates the stochastic element, yield per mature tree equivalent for 1972. This element is normally distributed with the mean and variance of the 1953–71 period. The product of the yield and the actual number of tree equivalents gives production (Fig. 1). The stochastic quality variable was generated along with the stochastic variable, other U. S. production.[11] Using the demand equations and a market policy, prices and quantities of fresh and processed apples were generated.[12] Also, total grower revenue and the weighted average price were computed. This price plus the previous seasons' prices provide input to the tree response equation. Death loss due to attrition was computed.[13] Two independent stochastic freeze elements were generated—one for trees 12 years and older and one for trees under 12 years. The probability of each was 6 percent. When a freeze occurred, there was a 20 percent kill of trees in the appropriate age distribution. Death loss from a freeze took place over a period of three years, with two-fifths of those marked for death being killed in each of the first two years and one-fifth the third year. After the change in tree numbers was estimated, the age distribution was updated.

Results

Under the present allocation procedure (Market Policy 1), the expected present value of the 10-year stream of income is 357.36 million dollars with a standard deviation of 26.43 million dollars (Table 2). This is the lowest of the four policies. The variance of the expected present value is also the greatest. This is due to the nearly constant proportion allocated to the fresh market and the more inelastic fresh demand. With large crops, fresh prices are severely depressed. Policy 4, on the other hand, has the

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[10] The —0.5 cents per pound represents the cost of hauling fruit to a dump.

[11] The probability is .32 that quality is poor. U. S production was previously explained.

[12] Source of future population estimates is [12] Source of future per capita income estimates is [13].

[13] This was 1 percent per year for trees 20 years and under and 3.7 percent per year for trees over 20 years

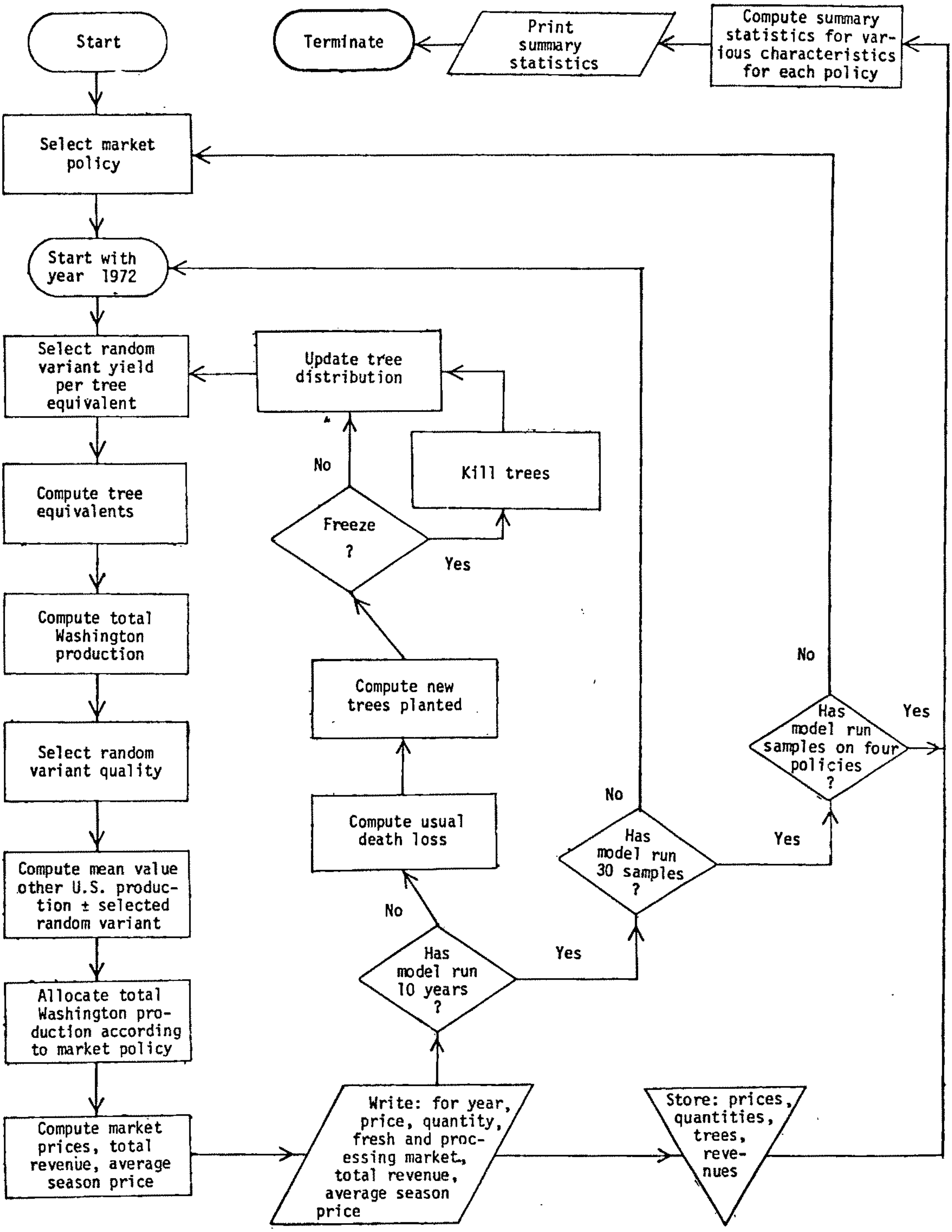
Start
Select market policy
Start with year 1972
Select random variant yield per tree equivalent
Compute tree equivalents
Compute total Washington production
Select random variant quality
Compute mean value other U.S. production ± selected random variant
Allocate total Washington production according to market policy
Compute market prices, total revenue, average season price
Write: for year, price, quantity, fresh and processing market, total revenue, average season price
Has model run 10 years ?
No
Compute usual death loss
Compute new trees planted
Freeze ?
No
Yes
Kill trees
Update tree distribution
Yes
Has model run 30 samples ?
No
Yes
Has model run samples on four policies ?
No
Yes
Store: prices, quantities, trees, revenues
Compute summary statistics for various characteristics for each policy
Print summary statistics
Terminate

Figure 1. Schematic diagram of the simulation model of Washington's apple industry

greatest expected present value with the smallest variance. This is due to its ability to allocate to the more elastic markets as production increases. With increased returns, tree numbers also increase.

Policy 1 produces a drop in expected average

Table 2. Mean and variance of the present value of the 10-year stream of income for four market policies[a]

Policy Name	Policy Number	Mean (million dollars)	Standard Deviation (million dollars)
Facsimile of present rules	1	357.36	26.43
Price equalization	2	396.36	14.98
Monopolist: 2 markets	3	524.70	18.34
Monopolist: 3 markets	4	526.28	13.87

[a] Discount factor equal to 10 percent.

PHD prices from 4.2 cents per pound in 1972 to 3.0 cents per pound in 1976. This causes a reduction in the total number of apple trees from 10.9 million trees in 1972 to approximately 7.0 million trees in 1981. Despite the removal of trees under Policy 1, expected production increases from 1,300 million pounds in 1972 to almost 1,800 million pounds in 1979. This is due to the large number of nonbearing trees now in the ground. These trees become increasingly productive, which tends to offset any decrease in production due to removal of trees until about 1980. By 1981 Policy 1 shows a production of 1,400 million pounds and a price of 5.7 cents per pound.

Under Policy 2, the price equalization model, prices decrease from 4.1 cents per pound in 1972 to 3.3 cents per pound in 1975. This causes the total tree population to be reduced from 10.9 million in 1972 to about 8.3 million in 1981. This is 1.3 million more than under Policy 1. Under Policy 2, production is 400 million pounds more than under Policy 1 by 1981.

With the discriminating monopolist type allocation, Policies 3 and 4 produce markedly different results. These policies allocated a much greater proportion of production to the more elastic processing market. Under Policies 3 or 4 the lowest price is 4.0 cents per pound despite the fact that production is considerably greater. While Policies 1 and 2 demonstrate about a 50 percent increase in expected production, Policies 3 and 4 show an almost doubling of production. Because of these relatively high prices, increases in the state's tree population take place. By 1981 expected total numbers of trees are 11.4 million under Policy 3 and 11.8 million under Policy 4. By the late 1970's, tree numbers are stabilized.

In summary, Policies 3 and 4 result in greater expected average *PHD* prices and greater expected revenues. Greater prices result in large increases in production, but by 1981 tree plantings are about equal to replacements with average PHD prices stabilized. If Washington's apple industry adopts Policies 3 or 4, it must be willing to make certain changes. A marketing board with the mandatory power to divert between fresh and processing must be established. Also, the state must expand its processing capacity.

Model Credibility

Individual components of the model were in agreement with economic theory, and the estimates of the unknown structural parameters were statistically satisfactory. The output of the simulation seemed reasonable to individuals familiar with the industry. Certain structural coefficients within the model were parametrically varied and the model's output examined. The results appeared reasonable under the altered coefficients.

The authors have made no attempt to replace the stochastic elements with actual past data and to run the model to validate its ability to reproduce the past. First, there is insufficient information to make such a comparison. It is impossible to specify accurately the age distribution of the state's apple trees for earlier years because of lack of data. Reasonable estimates of the age distribution of trees have been available only in recent years.

Second, the authors believe simulation models should not be evaluated solely on their ability to predict the past. Following the argument by Raulerson [10], the important criterion is how well the model explains and contributes to the understanding of the system under study. For policy evaluation purposes, revealing the nature of the system under study is more important than predicting the past.

Summary

Proposals for monopolist allocation models for perennial crops are quite common. Yet, increasing grower returns by discrimination among markets may be shortsighted. The effect of higher grower revenues upon supply was incorporated into a simulation model of Washington's apple industry. Supply was restricted with a polynomial distributed lag. The simulation included stochastic elements to specify the effects of weather and fruit quality.

Under the monopolist allocation policies, expected production nearly doubles. This increased production is sold in the more elastic processing market, thus creating expected revenues well in excess and with less expected variation than those under the present policy. The monopolist policies produced expected prices slightly above or equal to the average cost of production. Under present allocation policy, prices declined and trees were removed. At the end of the time horizon, expected grower prices are about equal to production costs, producing stable tree numbers and stable production under the monopolist type model.

Thus, although a supply response from increased prices under the monopolist policy did occur, discounted returns to growers were much higher than under present policy. The greatest benefit from models such as this one is their ability to give an industry an insight into the future under alternative actions. These models can be used by growers to examine the future implications of other market alternatives.

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The Egg Cycle and the Ability of Recursive Models to Explain It*

DAVID G. HARTMAN

The often-discussed instability of the price of eggs is examined by use of spectral analysis, and the existence of an egg cycle is confirmed. In explaining the cycle, the familiar cobweb model is shown to be inferior to an alternative model. The alternative model, proposed by Nerlove, has producers planning changes in their production levels in response to prices, with the changes being realized only after a lag. Economic justifications are given for such producer behavior to continue, even though it causes instability. Recent destabilizing influences, not related to the cycle, are also discussed.

Key words: **egg cycle; recursive model; expectations; cobweb theorem; price cycles.**

EGG PRODUCERS and their spokesmen complain of egg prices fluctuating so greatly that egg farms are often operated at a loss. Masters, for example, reports that even very efficient producers have been driven out of business by the egg price cycle [11] and that this is explained "quite well" by the cobweb theorem [12]. Attempts to incorporate lagged price in econometric models to explain egg production, however, met with little success [5, pp. 12, 18]. The purpose of this paper is to determine if a price cycle does exist for eggs and, if so, to what extent it results from the cobweb or a similar recursive phenomenon.

Existence of an Egg Price Cycle

An egg cycle longer than the one-year seasonal is not obvious in the 16-year series of quarterly price paid to farmers for eggs (Fig. 1).[1] However, when the series is deseasonalized (by subtracting from each observation the mean of the previous five observations on the same season), an egg cycle is more visible (Fig. 2). To confirm the existence of an egg cycle and determine some of its properties, modern time-series analysis is used.

First, the autocorrelation function of monthly egg prices for up to 50 lags is computed and graphed in Figure 3, along with an approximate 95 percent confidence-interval of the type suggested by Jenkins and Watts [7, p. 187] for testing "white noise." In addition to serving as the basis for further calculations, the autocorrelation function permits a test of the possibility that the fluctuations in egg prices are random, or "white noise." Points lying outside the confidence-interval imply at least 95 percent certainty that fluctuations in egg prices are not random. However, the obviously high degree of seasonality in egg prices could account for the non-randomness. For this reason, the autocorrelation function for monthly prices deseasonalized (by subtracting the average of the five previous observations on the same month) is graphed in Figure 4. The null hypothesis of random fluctuations is again rejected and for many different lag lengths. These tests show that the deviations of egg prices around their seasonal normal are somehow consistent, so the existence of an egg cycle cannot be ruled out.

To gain more insight into the consistency of these fluctuations, the spectral density function is computed, with the weighting function similar to the Tukey-Hanning function [6]. The graph of the spectral estimate on the raw price data is shown (Fig. 5) to have two very definite peaks in frequency bands corresponding to two dominant cycles in the data: one of about 12.5 months (.08 cycles per month) and one of about 33.3 months (.03 cycles per month). Spectral investigation has therefore confirmed the existence of an egg cycle of length about 33 months.[2]

In order to check the method of deseasonalization used (the method is also used on quarterly data before the subsequent regressions are performed), the spectral density is computed for the deseasonalized data and shown in Figure

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* This article is based on my 1973 Northwestern University master's thesis. I wish to thank Richard B. Westin for his helpful guidance (and my friends at the Commodity Exchange Authority for my interest in agricultural economics). The *AJAE* referees and editors also provided useful suggestions on an earlier draft of this paper.

[1] These data are from [4], with current figures published in [20].

[2] Weiss [24], also using spectral methods, supports the existence of seasonal and cyclical egg price movements.

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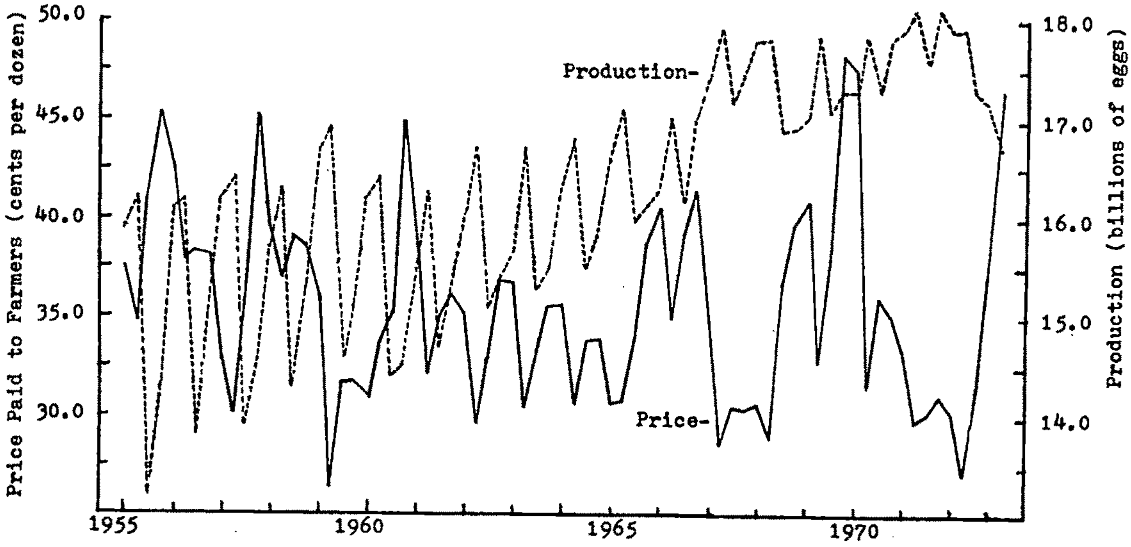

Figure 1. Quarterly price and production of eggs

6. A comparison of Figures 5 and 6 reveals that the process of deseasonalization removed the one-year seasonal cycle while leaving the longer cycle intact. Hence, deseasonalization seems to have accomplished its goal.[3]

The Cobweb Theorem and Later Reformulations

Traditionally, the main explanation for cycles in agricultural prices has been the familiar cobweb theorem. The egg industry seems to fit the assumptions of the cobweb model especially well. Eggs are highly perishable, and, although they can be stored, storage eggs do not substitute well for fresh eggs. Consequently, the

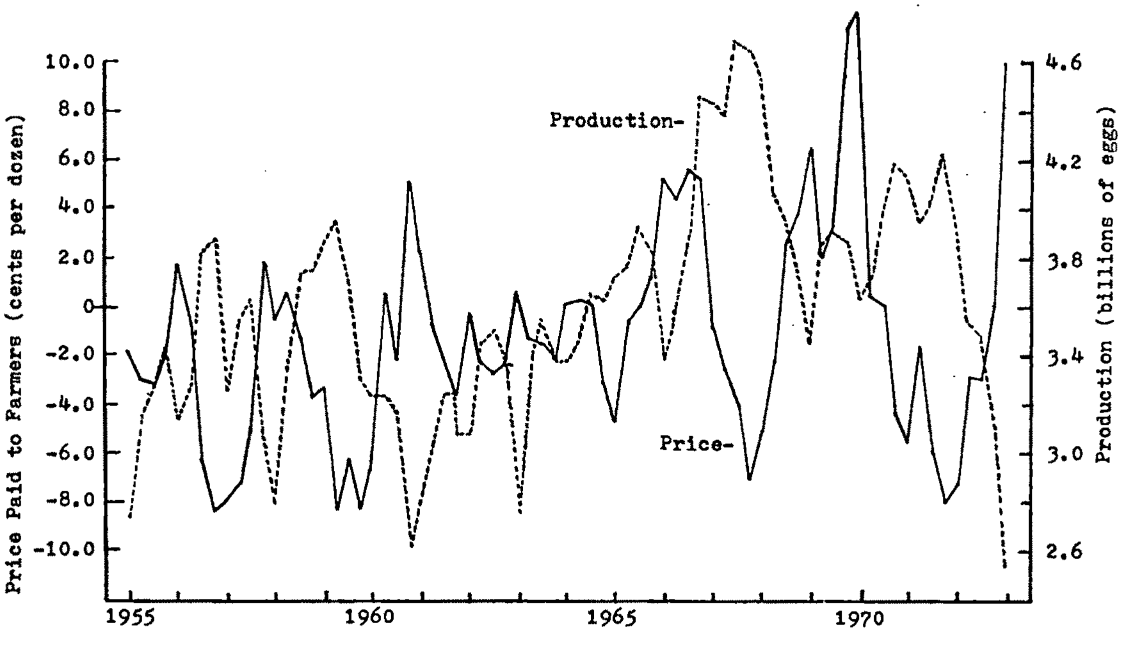

Figure 2. Deseasonalized quarterly price and production of eggs

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[3] For a discussion of both the computation of the spectral density function and the analysis of seasonal adjustment procedures by use of spectral analysis, see Nerlove [15].

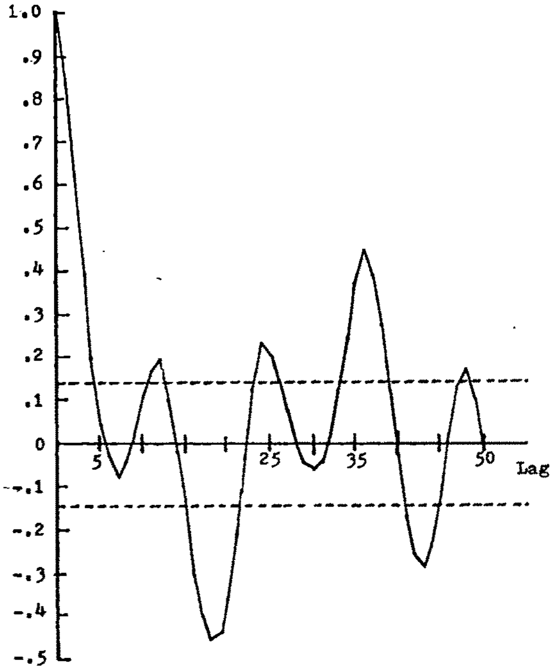

Figure 3. Autocorrelation function of egg prices, with 95 percent confidence-interval (dashed lines)

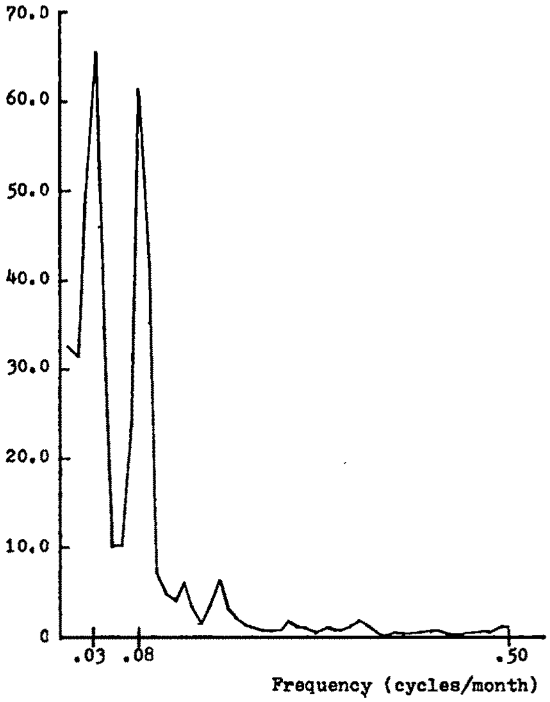

Figure 5. Spectrum of egg prices

supply of eggs is highly dependent on current production. The level of current production, in turn, depends mainly on the number of laying chickens. Since it takes about six months for a new layer to be hatched and grow to laying age, and several more months to reach peak productivity, postulation of a fixed production

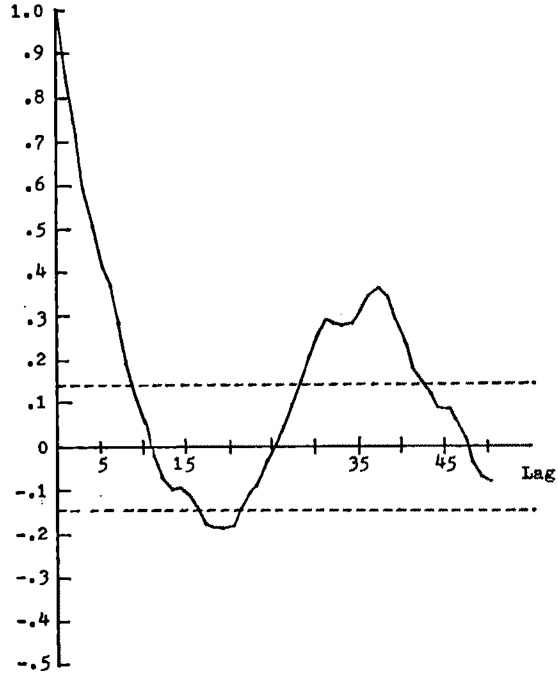

Figure 4. Autocorrelation function of deseasonalized egg prices, with 95 percent confidence-interval (dashed lines)

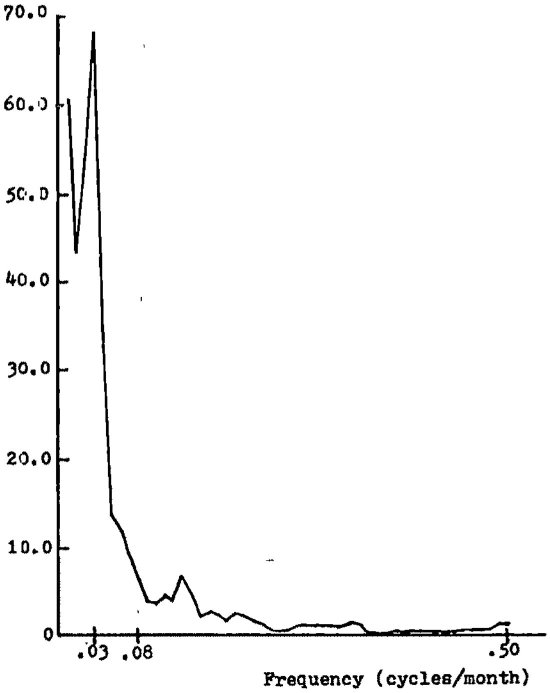

Figure 6. Spectrum of deseasonalized egg prices

lag seems reasonable. More recently, though, the cobweb explanation for agricultural cycles has been criticized as "improbable" for its reliance on a short-run supply curve which must be reversible along its entire length, as a long-run curve is [1, 2]. This criticism prompted the formulation by Nerlove and Larson [9, 10] of recursive models that do not rely on such short-run curves that are hardly short-run curves at all. A well-defined and thoroughly-examined (theoretically) model is Larson's harmonic motion model.

The harmonic motion model results from a small, but important, modification in the cobweb. Like the cobweb model, the harmonic motion model relies on the assumptions of prices being determined by current production and of a fixed lag between the forming of producers' plans and the plans' realization. However, while the cobweb model postulates that producers plan to produce a given amount (based on current price), the harmonic motion model assumes that producers plan output changes on the basis of current price, with the "strength of the response . . . proportional to deviation from [long-run] equilibrium" [10]. Larson pointed out that besides altering the assumptions made about producer price response to reflect more clearly the results of studies on producer behavior in various agricultural industries, the harmonic motion model also leads to price cycles of length equal to four times the fixed production lag, instead of twice the length of the lag as in the cobweb model [10].

The modification made by Larson apparently makes the new model much more appropriate than the normal cobweb for explaining the egg cycle. As has been pointed out, it takes eight or nine months for an efficiently-producing layer to be produced. Hence, the harmonic motion model has a potential not shared by the simple cobweb for explaining the approximately 33.3 month egg cycle observed.

Testing the Newer Models

Although criticism of the cobweb model has been strenuous, very little use has been made of the newer cycle theories which attempted to answer that criticism. Larson's model is difficult to use since it involves continuous variables and includes variables measured as deviations from long-run equilibrium. For this reason, the model which Nerlove presented as an "alternative but equivalent formulation" to his adaptive expectations model [13] will be used to test the applicability of Larson's model to the egg industry.

Although expressed differently, Nerlove's equations rely on the same behavioral relationships as Larson's model:

$$(1) \qquad Q_t^d = a + b\,P_t$$

$$(2) \qquad Q_t^s - Q_{t-1}^s = \gamma(\bar{Q}_t^s - Q_{t-1}^s), 0 < \gamma \leqslant 1$$

$$(3) \qquad Q_t^s = Q_t^d.$$

Equation (1) simply indicates that the quantity demanded is a linear function of price. Equation (2) indicates that changes in the quantity produced are proportional to the deviation of output (or, equivalently, price) in the previous period from equilibrium. To make the relations testable, however, Nerlove adds another equation,

$$(4) \qquad \bar{Q}_t^s = c + d\,P_{t-1},$$

which in this simple case implies that producers see price in the preceding period as the basis for making long-run plans. Larson makes a similar assumption but interprets $\bar{Q}_t^s$ as the actual long-run equilibrium value, not just the "normal" as viewed by producers. For eggs about three quarters are needed for the plans to be realized, so equation (4) must be replaced by

$$(5) \qquad \bar{Q}_t^s = c + d\,P_{t-3}.$$

Solving (2) and (5),

$$(6) \quad Q_t^s = \gamma c + \gamma d\,P_{t-3} + (1-\gamma)\,Q_{t-1}^s.$$

For notational simplicity, the following model is adopted to explain egg price and production fluctuations:

$$(7) \qquad P_t = a_1\,Q_t + a_2\,B_t + a_3\,T + a_4$$

$$(8) \qquad Q_t = b_1\,P_{t-3} + b_2\,Q_{t-1} + b_3\,S_{t-3} + b_4\,T + b_5$$

where[4]

P_t = average quarterly price of eggs received by farmers in the U. S. in cents per dozen,

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[4] The source of all data is [4], with the original sources being USDA publications. Current sources for the data are as follows: prices of eggs and cattle paid to farmers—[20], production of eggs—[21], and price of 44 percent protein soybean meal (Chi.)—[19]. All quarterly observations are constructed from monthly values and deseasonalized by subtracting from the observation the mean of the values for the same quarter in the previous five years. Production has shown a two-thirds decline in seasonality over the 16-year period under consideration, so each observation is deseasonalized by subtracting eight-tenths of the average value for the previous five years.

Q_t = total quarterly production of eggs in the U. S. in billions of eggs,

B_t = average quarterly price of beef cattle paid to farmers in cents per pound,

S_t = average quarterly price of 44 percent protein soybean meal,

and

T = linear trend.

Equation (7) is derived from (1) by making P_t the dependent variable to reflect the fact that price responds to a predetermined level of production, and by including for realism B_t (the price of beef, often regarded as a substitute good for eggs) and T (useful as a proxy for factors such as tastes and population). Equation (8) is derived from (6) by including for realism S_{t-3} (the price of soybean meal, a feed ingredient, as a cost of production during the period of planning) and T (a proxy for such factors as productivity).

Equations (7) and (8) are not simultaneous, and the coefficients may be estimated using OLS, with the following result[5,6] (standard errors in parentheses):

(9)

$$P_t = -\underset{(1.08)}{5.50}\,Q_t + \underset{(.15)}{.30}\,B_t + \underset{(.03)}{.20}\,T + \underset{(3.52)}{11.3}$$

$$R^2 = .53,\ \mathrm{d} = 1.00$$

(10)

$$Q_t = \underset{(.009)}{.03}\,P_{t-3} + \underset{(.09)}{.75}\,Q_{t-1} + \underset{(.004)}{.001}\,S_{t-3} + \underset{(.003)}{.00002}\,T + \underset{(.28)}{.93}$$

$$R^2 = .75,\ d^* = .069$$

The result obtained for equation (9) indicates that price of eggs is dependent on current production.[7] More significantly, equation (10) shows the production of eggs to be highly dependent on both level of production the previous quarter and on price of eggs three quarters before. This indicates that production changes occur in response to price, as Larson's model predicts. The results are more encouraging when it is remembered that the percent of variation explained in both equations is based on the variance after the highly seasonal variables were deseasonalized. Also, the value obtained for d^* does not allow rejection of the null hypothesis of no error autocorrelation at even a 10 percent level of confidence. Hence, the regressors have eliminated the cycle found in egg production so that no significant autocorrelation remains.[8]

As a check on the postulated production lag length, egg and soybean meal prices lagged from one to eight quarters were used in new regressions in place of the P_{t-3} and S_{t-3} of equation (8).[9] The best R^2, d^*, and t-value for the lagged price variable were obtained with the original three-quarter lag.

For comparison a regression was done on a supply equation of the simple cobweb type. The result was as follows:

$$Q_t = \underset{(.014)}{.02}\,P_{t-3} + \underset{(.006)}{.001}\,S_{t-3} + \underset{(.004)}{.01}\,T + \underset{(.18)}{3.14}$$

$$R^2 = .37,\ d = .53$$

A much less satisfying result is obtained, and some sort of consistency still exists in the residuals, as evidenced by the Durbin-Watson statistic that rejects the null of no autocorrelation at the 95 percent confidence-level. When a check is made of the length of the fixed production lag, the best result by far is obtained when the P_{t-3} and S_{t-3} in the above equation are replaced by P_{t-5} and S_{t-5}. It is difficult to accept the proposition that using one quarter's price to make decisions affecting future production, a farmer would choose to use the price prevailing half a year before. As Larson's work suggests, the cobweb theorem results in cycles shorter than

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[5] The data used are for the years 1955 through 1970. For years prior to 1955, deseasonalizing the data requires use of observations before 1950, when the government was involved in the egg market. For years after 1970, other factors may have temporarily invalidated the relations.

[6] d is the ordinary Durbin-Watson statistic. d^* is the statistic adjusted for use when a lagged dependent variable is included in the regression. A test for autocorrelation uses d^* tested for being standard normal [8].

[7] Since the Durbin-Watson statistic is fairly low, the estimated standard errors are possibly biased. Hence, even though the estimated t-value for the Q_t coefficient is above five, the test is not totally reliable. Because (7) is not expected to be controversial, the author simply assumes that the bias is not so great as to let Q_t be insignificant.

[8] Spectral analysis confirms the existence of a cycle in production that opposes that in price. The cycle is also obvious in Figure 2.

[9] Since the coefficient of S_{t-3} is insignificant in all regressions, the lag of this variable is changed only to be consistent with the lag of P. Of course, no information is available from the S variable regarding the proper lag length.

those observed; a lag of about twice the length of that which seems most reasonable is necessary to produce the observed cycles.

A More Sophisticated Expectations Model

Since the model defined by equations (7) and (8) was based on the quite naive theory of plans being made on the basis of current prices only, the model may be improved by assuming that a producer takes some distributed lag function of past prices into account in determining his expectation of long-run equilibrium.[10] Also, such a model would seem more in line with Larson's idea of decisions being made on the basis of deviations from actual long-run equilibrium (measured as a trend in prices).

A Koyck lag structure [by simply introducing another Q_{t-1} into equation (8)] would not alter the model; therefore the Fisher linearly-declining lag structure was used [14]. It involves a linear function of past prices normalized for the number of prices included, of the form (for use of two prices): $(2P_{t-3} + P_{t-4})/3$. Inclusion of various numbers of past prices in the function was tried, but the best result (in terms of variance explained) was:

(11)

$$\begin{aligned} Q_t = \underset{(.01)}{.04\,\hat{P}_{t-3}} + \underset{(.09)}{.70\,Q_{t-1}} + \underset{(.0007)}{.00001\,\hat{S}_{t-3}} \\ + \underset{(.003)}{.001\,T} + \underset{(.29)}{1.12} \end{aligned}$$

$$R^2 = .754, d^* = .54$$

where

$$\hat{P}_{t-3} = (3\,P_{t-3} + 2\,P_{t-4} + P_{t-5})/6$$
$$\hat{S}_{t-3} = (3\,S_{t-3} + 2\,S_{t-4} + S_{t-5})/6.$$

The result is a slightly better explanation of variance than that obtained from equation (9) but a slightly worse cycle reduction (measured by the difference between d^* and zero). Thus, introducing more realism and approximating Larson's model more closely did not diminish the strength of the evidence that the model is applicable.

Expansion and Contraction of Output

Part of the controversy over the supply curve used in the cobweb theorem centers on the possibility that a producer's response in cutting production may be different from that in expanding. Gerra [5] has argued that in the case of eggs the responses are indeed different. If he is correct, the cobweb theorem, by relying on a reversible supply curve, is theoretically inapplicable to the egg cycle.

Gerra argues that producer response may be greater to price increases for eggs than to declines. Entry into the egg industry, especially on a small scale, is easy, so planned production increases in response to favorable prices may be substantial. On the other hand, if prices are unfavorable, producers should stay in the industry in the short-term if they meet their variable costs (mostly the cost of feed: estimated usually at half the 25 to 30 cent cost of producing a dozen eggs). It is unlikely that this variable cost would not be met.[11]

To test the equality of response to price increases and declines, the following estimation was performed:

(12)

$$\begin{aligned} Q_t = \underset{(.09)}{.75\,Q_{t-1}} + \underset{(.01)}{.04\,P_{t-3}{}^i} + \underset{(.01)}{.01\,P_{t-3}{}^d} \\ + \underset{(.004)}{.002\,S_{t-3}} - \underset{(.003)}{.001\,T} + \underset{(.28)}{.93} \end{aligned}$$

$$R^2 = .76, d^* = .91$$

where

$$\text{if } P_{t-3} \geqslant P_{t-4}, P_{t-3}{}^i = P_{t-3} \text{ and } P_{t-3}{}^d = 0$$
$$\text{if } P_{t-3} < P_{t-4}, P_{t-3}{}^d = P_{t-3} \text{ and } P_{t-3}{}^i = 0.$$

The impact of price increases on production is much greater than that of declines as Gerra suggested. In addition to t-values which show this difference, the coefficients of $P_{t-3}{}^i$ and $P_{t-3}{}^d$ differ (in a t-test) at the 90 percent level of confidence.[12] In rejecting the equality of responses, the applicability of the cobweb theorem to the egg industry can be rejected with the same confidence.

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[10] The theory should also include the lagged price of soybean meal in a manner similar to the lagged price of eggs. However, coefficients for the soybean meal variable are insignificant in all regressions and are often of the wrong sign as well.

[11] Gerra also argues that the lag may be longer for contracting output than for expanding because it is necessary to wait for the number of layers to decline. However, since Gerra wrote his article, replacement of layers has stopped taking place mainly in the spring. Also, layers are profitable for only about a year unless costly forced-molting methods are used. The relatively high and continuous level of replacements necessary would seem to make reductions subject only to the normal chick-producing delay.

[12] To test the additional hypothesis that the lengths of the two lags might differ, various combinations of lags for P^i and P^d were tried in reestimating the equation. The best t-value for the coefficient of $P_{t-j}{}^i$ results when j equals three, the best also for $P_{t-j}{}^d$ when j equals three. Thus lags attached to the responses are the same, according to this test.

Use of More Recent Data

As has been pointed out, outside factors have had such a great impact on the egg industry that no data after 1970 were used. A Marek's disease vaccine, which increased the survival rate of chicks by an unexpected amount and also increased the rate of lay of treated chickens, was given to nearly every chick by about the second quarter of 1971. The vaccine's unexpected success raised production far above the level any model could predict on the basis of producer planning. In 1972, exotic Newcastle's disease was discovered in the U. S. To prevent spread of the disease, chickens which had been exposed, nearly 3 percent of the nation's total flock, were destroyed. To test the effects of these factors, the supply equation (8) is reestimated using data through 1972.

The residuals from this regression confirm the impacts of exogenous shifts in supply. During the period of the Marek's disease vaccine introduction, production of eggs was at least 2 percent larger than predicted by equation (8). During the period of the Newcastle's disease flock reductions, production of eggs was 3 percent lower than estimated by the supply equation. Residuals obtained during these periods were among the largest of the entire 18-year period of estimation, and a Chow test for equality of all coefficients between the periods 1955–70 and 1971–72 rejects the null of equality at the 90 percent level of confidence [3].

Producers would be expected to adjust their behavior to these new factors with a lag according to the postulated model. Sufficient data are not yet available to test this adjustment. However, the consistency of the residuals in the last two years with expected impacts of outside factors provides some evidence that the relationship expressed in equation (8) is still operating.[13]

Why the Cycle Continues

Testing of the model defined by equations (7) and (8) has confirmed the validity, as far as the egg industry is concerned, of the approach taken by Larson and Nerlove to recursive models. Producers appear to plan production changes on the basis of price expectations, which can be approximated as some function of past and current prices. Since these production changes take about three quarters to be realized, a cycle in prices and production results. The deviations from this rule in the past two years result from exogenous shifts in egg output and should not diminish the impact of the model's results. One fundamental question remains, however: why do farmers not realize that cycles exist and change their behavior to reduce rather than perpetuate the cycles in the prices they receive?

Weiss, in explaining the persistence of cycles in agriculture, cites the impact of other factors on farm prices, factors such as "weather . . . the prices of other goods, and changes in demand" [23]. He states that without these other impacts, "farmers could probably figure out what was happening to them." The effect of such factors appears to be important in the egg industry, when it is considered that in the estimation of the demand equation, even with one outside factor, the price of beef, included, only about half of the variation in deseasonalized egg prices is explained. When egg prices and production were shown in Figure 1, the egg cycle was obscured by seasonal and exogenous fluctuations. So, although industry economists attribute egg price movements to the cobweb theorem, it is unlikely that individual producers, especially small producers, discern a cyclical pattern.

Large egg cooperatives, though, employ economists (such as Masters) who recognize the existence of egg price cycles. It would seem then that cooperative action could diminish the fluctuations. United Egg Producers (UEP), representing about 60 percent of U. S. egg production, has tried to bring about voluntary production control. As with any voluntary program, however, producers only follow the guidelines when they expect to gain from following them. In 1970, when egg prices threatened, according to UEP, to fall below production cost in the upcoming decline, UEP's "Action Now" program for reduction of layer hatchings was a success. During the Phase II program, however, "The success of the first program, apparently, went to the heads of many in the industry . . . Too many producers were confident that enough others would follow the Phase II suggestions, so that massive overproduction would be averted" [16]. If others follow the suggestions, production will be low and prices high, and a farmer can make great profits by increasing his own output while others are reducing. But even if he expects others not to follow the guidelines, he cannot improve his own position by reducing production unless negative profits are expected. When prices are expected to fall to near production cost, producers have little to lose by cooperation. Otherwise, cooperative action does not appear likely to be in the individual's best interest.

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[13] Another source of instability appeared in 1973 as feed prices reached unprecedented highs. Since soybean meal price coefficients were insignificant in all the regressions in this study, this statement may seem strange. However, the estimations reported here rely on soybean meal price observations, the greatest of which is less than one-third as large as values common in mid-1973. Such a rise in an important factor of production would be expected to have a significant impact on production, as it apparently did. The situation provides a reminder that relationships estimated from observed values should not be assumed to hold for new values outside the range (and especially far outside the range) of original observation. Using linear regression is usually simply a method of approximating a segment of some function, thought to be nearly linear on that segment, by a linear function. Just as an estimated demand equation will seldom tell the researcher what level of production would be required to drive price very low (eg., to zero), an estimated supply equation will often fail to explain producer responses to unparalleled factor price increases. If such feed price movements become commonplace, the results reported here will have to be re-evaluated.

Also working against cooperative supply control is the large number of egg producers. A 1970 USDA study found that in 1964, although there were a growing number of farms with over 100,000 layers (138 farms representing 7.6 percent of U. S. egg production), there were still 896,203 farms with flocks of less than 100 chickens. In fact, about 38 percent of U. S. egg production was on 1,197,115 farms each with less than 3,200 layers [22].[14]

Factors besides producer price expectations may also serve to strengthen the cycles. Small producers may be forced out of business during price declines, or at least be forced to curtail layer replacement. The higher prices and profits which follow cause some farmers to reenter (or enter for the first time) the industry, or be able to afford to step up replacement of layers if they have stayed in business. Larger producers may, in times of favorable prices, invest in equipment which they could not afford during the decline.

UEP has cited yet another factor involved in strengthening the cyclical fluctuations: the federal income tax law. In 1915, as an aid to small farmers naive in accounting techniques, a rule was adopted allowing use of cash accounting. Using this method, a farmer may deduct immediately all costs of production incurred in a given year, even though the costs may relate to production to be realized in future years. For example, if a layer is needed in January 1975, it can be hatched and fed up to laying age as a cost of production deductible in 1974, although the first egg may be laid in 1975. Obviously, there is an incentive to expand operations during years when profits are high and perhaps not even to replace old layers when profits are low, waiting for a time when the tax deduction is needed more. The savings involved have been a "tremendous incentive" for expansion in times of high prices, according to an October 1972 *Egg Industry* editorial.

The existence of egg price cycles of the type discussed by Nerlove and Larson has been confirmed by the methods of spectral analysis and least squares regression. Although the cobweb model has been rejected as an explanation, the model used has similar implications about the behavior which leads to the cycles: producers plan for the future on the basis of factors which are no longer relevant when the plans are realized. Possible explanations for the persistence of such behavior are many: the cycles are difficult to distinguish; only under very special circumstances is it better for individuals to act to reduce the cycles; and producers may be forced (by limited funds or tax advantages) to contract output potential when prices are low and they may be able to afford expansion only when prices are high. Economic analysis thus supports the statistical results obtained: the type of producer behavior described by Larson transforms a seven to nine-month production lag into cycles in egg prices and production of nearly three years in length, reducing prices to near or below production costs in some cases.

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[14] Rausser and Cargill [17] have found cycles in chick and broiler prices of 32 and 30 months respectively, but the latter was not significant at the 95 percent level. Their work is suggestive that vertical integration in the broiler industry has played a stabilizing role with respect to price cycles. Although other market factors differ in the broiler and egg industries (such as the growth of the former and the declining nature of the latter), the trend toward greater concentration and integration of egg production may prove significant in the future.

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Short Articles and Notes

Food Demand Matrix in an Approximate Linear Expenditure System*

KOZO SASAKI AND YOSHIKIYO SAEGUSA

The demand system or matrix for food commodities and commodity groups in Japan is constructed. A demand matrix is obtained by an alternative version of the linear expenditure system, implying a practical and convenient approximation to Powell's system. Indicators of goodness of fit are quite high for the system developed.

Key words: **demand system; food; subgroup.**

A COMPLETE system approach is required to carry out the demand analysis of food in an efficient and comprehensive fashion. It may be regarded as an attempt to narrow the gap between theory and empirical analysis.

A demand system on the utility basis is desirable from the theoretical viewpoint and has several advantages in its empirical applications and interpretation. A complete set of demand functions can be efficiently estimated by making use of *a priori* restrictions on the behavioral parameters available from demand theory. It is also possible to specify the functional forms of utility and demand functions, so that the utility and demand structures may be analyzed in detail. Demand systems with a theoretical consistency assure that all expenditures on individual commodities add up to the aggregate consumption. Such systems can be exploited as a submodel of a macro-economic model.

The linear expenditure system is a complete set of demand relations satisfying all the restrictions of demand theory. The system also fits alternative data sets well (see [3, 20]). Linear expenditure systems developed by C. E. V. Leser [7, 8] and by A. A. Powell [13, 14] are theoretically examined and compared to the one introduced by J. R. N. Stone [18] and are empirically tested.

Leser and Powell's systems are first applied to empirical data because of their computational simplicity. It is found that both systems face some difficulties in the demand analysis of subgroups of food commodities. The difficulties indicate that valid estimates were not obtained in both systems for the parameters of a few commodity groups. A more practical alternative version is proposed here for empirical analysis by combining the two systems mentioned above. It is also applied to the same expenditure and price data. Results obtained within this context are compared and examined from various angles.

The data used are taken from [9], and in accordance with the source, the expenditure data handled in this study are shown in terms of "yearly average of monthly expenditures" per capita. Price data available for this purpose are from the Consumer Price Index by Subgroups. Expenditure and price data are evaluated at 1965 yen, deflating the original data by the General Consumer Price Index. All real prices in 1965 are set equal to 1.

For the systematic food demand analysis, all commodities are first classified into 10 commodity groups—nine subgroups of food commodities and a broad category of non-food items:

1. Rice
2. Other cereals
3. Fish
4. Meat
5. Milk and eggs
6. Vegetables
7. Fruit
8. Food consumed outside household

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9. Other food (Dried and processed food, Condiments, Cakes, Beverages)
10. Non-food (Housing, Fuel and light, Clothing, Miscellaneous).

Then a rational means of commodity grouping is sought. Before the empirical analysis is presented, the theoretical basis of the linear expenditure system is discussed.

Theoretical Structure of Alternative Linear Expenditure Systems

A complete set of linear expenditure functions for k commodities is generally described in the form

$$(1)\quad p_i x_i = \Sigma_j a_{ij} p_j + b_i E + c_i \; (i,j = 1, \ldots, k)$$

where p_i and x_i indicate the price and quantity consumed per capita of the ith commodity, E denotes income or total expenditure per capita, and a_{ij}, b_i, and c_i represent behavioral parameters to be estimated. Imposing the three theoretical properties[1] of additivity, homogeneity, and symmetry provides equation (1) with the expression

$$(2)\quad p_i x_i = p_i \beta_i + b_i (E - \Sigma_j p_j \beta_j), \qquad \beta_j \equiv \begin{cases} a_{ij}/(1 - b_i) \; (i = j), \\ -a_{ij}/b_i (i \neq j). \end{cases}$$

β_i and β_j are unknown parameters as defined above, representing the minimum required quantities of the ith and jth commodities, respectively. They are assumed to be non-negative. Equation (2) is called Stone's linear expenditure system [18], which was originally derived from L. R. Klein and H. Rubin [6]. The number of unknown parameters is reduced from $(k^2 + 2k)$ in equation (1) to $2k$ in equation (2). The utility function underlying the above demand functions is that of the Stone-Geary form (see [2, 16]):

$$(3)\quad U = \Sigma_i b_i \log(x_i - \beta_i), \; b_i > 0, \qquad \Sigma_i b_i = 1, \; (x_i - \beta_i) > 0.$$

Utility function (3) satisfies the nonhomogeneity of utility functions, which is equivalent to the fourth property to be imposed on demand systems (see [20]).

Leser [7, 8] simplified the linear expenditure system for estimation purposes. The basic assumption introduced into Leser's system is characterized by its symmetry condition, indicating that all cross elasticities of substitution are taken as equal at the average level of all variables. With both theoretical properties and the additional assumption mentioned above, a_{ij} is expressed in terms of $(k + 1)$ other parameters, and equation (1) is accordingly transformed into the following equation:

$$(4)\quad p_i x_i = p_i \bar{x}_i + \bar{\alpha}(\bar{w}_i \Sigma_j p_j \bar{x}_j - p_i \bar{x}_i) + b_i (E - \Sigma_j p_j \bar{x}_j) \; (i,j = 1, \ldots, k).$$

$\bar{x}_i$ denotes the average value of x_i, which is defined as the average expenditure on the ith commodity divided by its corresponding average price. $\bar{w}_i$ and $\bar{\alpha}$ represent the average budget share of the ith commodity and the unique elasticity of substitution obtained at the average level of all variables, respectively. The unknown parameters in equation (4) are $(k + 1)$ in number, with one of them common to all equations. They are estimated by the generalized least squares method, minimizing the total sum of squared residuals over all expenditure equations (see [14, 17]).

The existence conditions of an indirect utility function were pointed out for the above demand functions by the present authors [15]. Gorman's theorem (see [11]) asserts that there exists an indirect utility function (5) at the average level of all variables

$$(5)\quad V = -\Sigma_i b_i \log p_i + \log[E - (1 - \bar{\alpha}) \Sigma_i p_i \bar{x}_i] + c \; (c\text{: constant}),$$

only if the marginal budget share and average budget share are equal for all commodities; i.e.,

$$(6)\quad b_i = \bar{w}_i.$$

The corresponding direct utility function is of the form

$$(7)\quad U = \Sigma_i b_i \log[x_i - (1 - \bar{\alpha}) \bar{x}_i].$$

The demand system derived from utility function (7) violates, at the average level, the fourth property that income elasticities are not all equal to one (see [20]). Thus Leser's system is basically a statistical demand model without the corresponding non-homogeneous utility function.

Under directly additive preferences, Powell

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[1] Any demand system should possess the following three properties if it is obtained through the utility maximization subject to the budget constraint:
(i) The expenditures on individual commodities add up to income or total expenditure (additivity).
(ii) Demand functions are homogeneous of degree zero in prices and income (homogeneity).
(iii) Cross substitution effects and cross elasticities of substitution are symmetric (symmetry).

[13, 14] introduced for the symmetry condition at the average level Houthakker's theorem [5]: cross substitution effects are proportional to the income derivatives of each pair of commodities concerned. As a result, equation (1) is rewritten as

$$(8) \qquad p_i x_i = p_i \bar{x}_i + \bar{\lambda} r_i + b_i(E - \Sigma_j p_j \bar{x}_j)$$

where

$$(9) \qquad r_i = b_i \Sigma_j b_j (p_j/\bar{p}_j - p_i/\bar{p}_i),$$

and

$$(10) \qquad \bar{\lambda} = -\bar{E}/\check{\omega},$$

the $\check{\omega}$ being the income elasticity of the marginal utility of income, evaluated at average prices and income. If the r_i's in equation (8) were known, the parameters could be determined by least squares, as noted for equation (4). However, equation (8) is nonlinear in $(k + 1)$ unknown parameters, so that an iterative approach by least squares would be necessary until convergence is achieved in all parameters. As first noted by Goldberger,[2] the underlying utility function belongs to the same class as the Stone-Geary type (see [4, 15]),

$$(11) \qquad U = \Sigma_i b_i \log(x_i - \beta_i)$$

in which

$$(12)$$
$$\beta_i = x_i - b_i \bar{\lambda}/\bar{p}_i,\ b_i > 0,$$
$$\Sigma_i b_i = 1,\ (x_i - \bar{x}_i + b_i \bar{\lambda}/\bar{p}_i > 0).$$

Empirical Analysis

At the outset, Leser's system was estimated on the basis of the generalized least squares method. Average elasticity of substitution $\bar{\alpha}$ was determined to be 0.60870 from observable data.[3] Thereafter, the ordinary least squares method was adopted to obtain marginal budget shares or income coefficients for respective commodity groups.[4] Estimated marginal budget shares are shown in Table 1. Each of them is highly significant from the statistical viewpoint. Marginal budget shares are positive for all commodity groups except commodity group 1, rice. Income elasticities in the linear expenditure system are generally expressed as the ratios of marginal to average budget shares. The estimates for the average income elasticities, $\bar{E}_i$'s, seem reasonable when compared with previous studies. All subgroups are confined to substitutes in the Hicks-Allen sense since the cross elasticity of substitution is set equal to a positive value for any pair of subgroups.

Table 1. Estimates of marginal budget shares and other parameters

System[a]	$\bar{\lambda}$	$\check{\omega}$[b]	Estimated Marginal Budget Shares b_i[c] 1	2	3	4	5	6	7	8	9	10
LS			—45534	6325	16583	48834	42980	14884	26732	34238	90180	764778
PS	5382.7	—209106	—43662	6945	—5378*	52309	43313	—4581**	27939	35334	97740	790041
APS	5520.4	—203891	—42837	6823	4132**	50921	42335	4485**	27366	34661	96381	775733

[a] LS = Leser's system; PS = Powell's system; APS = Approximate Powell's system.
[b] $\check{\omega}$ = Income elasticity of marginal utility of income, multiplied by 10^5 ($\check{\omega} = -\bar{E}/\bar{\lambda}$)
[c] The b_i's are multipled by 10^6.
* Significant at the 5 percent level under classical least squares postulates.
** Insignificant at the 5 percent level. Other b_i's are significant at the 1 percent level.

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[2] Professor Goldberger's result had not been available to the authors until they read Professor Hoa's paper [4] recently.

[3] The $\bar{\alpha}$ is determined in the following procedure:

$$\bar{\alpha} = \Sigma_i N_i / \Sigma_i D_i$$

where

$$N_i = \begin{vmatrix} \Sigma_t z_i^{(t)} y_i^{(t)} & \Sigma_t z_i^{(t)} u^{(t)} \\ \Sigma_t u^{(t)} y_i^{(t)} & \Sigma_t (u^{(t)})^2 \end{vmatrix},$$

$$D_i = \begin{vmatrix} \Sigma_t (z_i^{(t)})^2 & \Sigma_t z_i^{(t)} u^{(t)} \\ \Sigma_t u^{(t)} z_i^{(t)} & \Sigma_t (u^{(t)})^2 \end{vmatrix},$$

$$y_i = p_i x_i - p_i \bar{x}_i,$$
$$z_i = \bar{w}_i \Sigma_j p_j \bar{x}_j - p_i \bar{x}_i,$$
$$u = E - \Sigma_j p_j \bar{x}_j.$$

[4] In Leser's system, the estimation problem of the whole system of linear expenditure functions (1) is reduced to that of equation (4), and to that of the following equation:

$$y'_i = b_i u + \epsilon_i \quad (\epsilon_i\text{: residual term}),$$

where $y'_i = y_i - \bar{\alpha} z_i$ provided that $\bar{\alpha}$ is given. The similar procedure is adopted to estimate Powell's system (see [14, 17]). Estimates for price coefficients in this system are brought forth after income coefficients have been estimated.

Price coefficients, a_{ij}'s, and average price elasticities, $\bar{e}_{ij}$'s, can be derived from $\bar{\alpha}$, the b_i's, and observable data. Own price elasticities depend largely on the substitution elasticity. This tendency will become more evident for finely defined commodities. Thus it is difficult to obtain good estimates for own price elasticities in Leser's system.

Powell's system was subsequently estimated, using the results yielded by Leser's system. As the r_i's in equation (8) are not given, unknown parameters may be determined by applying least squares iteratively. The b_i estimates of Leser's system were taken as initial values of the b_i's which constitute the r_i's. The estimation procedure was iterated 15 times to accomplish the convergence of $\bar{\lambda}$ to five digits. Estimates of $\bar{\lambda}$ and b_i's are presented in Table 1. The sign of the marginal budget share changed from positive to negative for commodity groups 3 and 6. However, the level of significance is not very high for either estimate. These two marginal budget shares and, hence, the corresponding income elasticities appear incompatible with previous studies, in which both fish and vegetables have actually been viewed as normal goods. Such a discrepancy may be due to the assumption imposed on this system. The assumption of directly additive preferences would with difficulty fit finely defined commodities, even if it applies to broad groups of commodities. Other income elasticities are similar between the two systems.

It is possible to acquire price coefficients and average price elasticities for this system from estimated parameters and empirical data. Concerning price effects in Powell's system, own price elasticities vary substantially among commodity groups; in this respect Powell's system appears less restrictive than Leser's. The formula of price elasticity deduced in this formulation is identical with those derived by R. Frisch [1] and by H. S. Houthakker [5], since they equally assume the direct additivity of preferences.

It is a noteworthy fact, however, that the statistical properties of the estimators obtained in this configuration are not known, because the error structure is not specified. The b_i's are not maximum likelihood estimates (see [12]). Meanwhile, the total sum of squared residuals over all expenditure equations increased to a certain amount as the round of iterative estimation proceeded. The individual sum of squared residuals increased particularly for commodity groups 3 and 6 while it remained rather stable for the others.

It has been shown so far that Leser's system yields favorable estimates for income effects but not for own price effects and that Powell's system is likely to bring forth reasonable results for own price effects if appropriate estimates of income effects are available. There is a possibility of combining the two systems at the initial round when the total sum of squared residuals is small. Such a combination leads to an alternative version of the linear expenditure system.

The authors' approach is to curtail the estimation procedure of Powell's system, simply by substituting the b_i estimates of Leser's system into the r_i's in the estimation equation (8) and by treating these regressors as exogenous variables. Therefore, it may be called an approximate Powell's system. It has a considerable advantage in reducing computational burden and in improving the estimates of parameters from the empirical viewpoint. The unknown parameters are obtainable at the first round of the iterative estimation which has been performed. The b_i estimates of the approximate system are presented together with the results of other systems in Table 1. The sign of the estimates for groups 3 and 6 is now positive in line with the results of Leser's system, though their levels of significance are not sufficiently high. It is noted that the properties required for the underlying utility function are not fully satisfied because there is an inferior good, rice.

Average income and price elasticities are reported in Table 2. The income elasticities are close to those of Leser's system. The own price elasticities reported in the table differ between commodity groups more or less, as expected under the additive preference assumption. The positive sign of the own price elasticity for rice is not contrary to the fact that the price and quantity demanded tended to change in the same direction in the period under investigation. Among the three systems, income and price elasticities are considerably close with respect to meat, milk, and eggs, fruit, food consumed outside household, other food, and non-food.

Theoretical properties of additivity, homogeneity, and symmetry hold true at the sample means of variables. The additivity or adding-up criterion implies Engel and Cournot aggregations;

$$\Sigma_i \bar{w}_i \bar{E}_i = 1 \quad \text{(Engel aggregation)},$$

and

$$\Sigma_i \bar{w}_i \bar{e}_{ij} = -\bar{w}_j \quad \text{(Cournot aggregation)},$$

where $\bar{E}_i$ denotes the average income elasticity

Table 2. Income and price elasticities estimated for food commodity groups and non-food at the sample means of all variables, $\overline{E}_i$, $\overline{e}_{ij}$[a]

	1	2	3	4	5	6	7	8	9		10	
i j	Rice	Other cereals	Fish	Meat	Milk and eggs	Vegetables	Fruit	F.c.o.h.[b]	Other Food	All food	Non-food	$\overline{E}_i$
1. Rice	.334	.009	.020	.005	.006	.016	.004	.006	.038	.437	.132	.569
2. Other cereals	−.036	−.187	−.013	−.003	−.004	−.011	−.002	−.004	−.024	−.283	−.085	.369
3. Fish	−.010	−.002	−.057	−.001	−.001	−.003	−.001	−.001	−.007	−.084	−.025	.109
4. Meat	−.147	−.023	−.055	−.761	−.015	−.044	−.010	−.017	−.101	−1.172	−.353	1.525
5. Milk and eggs	−.132	−.021	−.049	−.012	−.688	−.040	−.009	−.015	−.091	−1.057	−.319	1.375
6. Vegetables	−.014	−.002	−.005	−.001	−.001	−.075	−.001	−.002	−.010	−.111	−.034	.145
7. Fruit	−.133	−.021	−.050	−.012	−.014	−.040	−.688	−.015	−.091	−1.065	−.321	1.386
8. F.c.o.h.[b]	−.119	−.019	−.044	−.010	−.012	−.036	−.008	−.618	−.081	−.947	−.285	1.232
9. Other food	−.082	−.013	−.031	−.007	−.009	−.025	−.005	−.009	−.474	−.654	−.197	.851
All food	−.001	−.017	−.026	−.069	−.059	−.022	−.038	−.050	−.160	−.444	−.134	.578
10. Non-food	−.122	−.019	−.045	−.011	−.013	−.037	−.008	−.014	−.084	−.352	−.915	1.267
$\overline{w}_j$[c]	.07524	.01850	.03791	.03339	.03078	.03101	.01975	.02813	.11320	.38791	.61209	

[a] $\overline{E}_i$ = average income elasticity of commodity group i; $\overline{e}_{ij}$ = average elasticity of commodity group i with respect to the jth price.

[b] Food consumed outside household.

[c] $\overline{w}_j$ = average budget share of commodity group j at average prices and expenditures.

of the ith commodity and $\overline{e}_{ij}$ indicates the average elasticity of the ith commodity with respect to the jth price. These equations are used together with the homogeneity condition to provide elasticities for all food in comparison with those for non-food. Effects of income and own price changes appear to be more evident than those of non-food price changes on the all food demand. In the present system the cross elasticities of substitution are positive between the normal goods. Hence those goods are substitutes in the Hicks-Allen sense. The cross elasticities of demand,[5] however, are negative for the normal goods, so that all the normal goods are *gross* complements (see [3, 13]). This follows since the income effects exceed the substitution effects for those goods. The cross elasticities of demand as a whole are observed to be relatively small in terms of absolute value, not only in the demand systems of the Powell form but also in Leser's system. The demand matrix tabulated here for the approximate system seems empirically better than the other two.

Comparison of the Results

Three different measures of goodness of fit are employed as standards of comparison for the estimated linear expenditure systems. They are the multiple correlation coefficient, the ratio of estimated quantity to actual quantity, and Theil's information inaccuracy (see [19]) for average budget shares. Multiple correlation coefficients, R's, were calculated as the simple correlation coefficients between actual and estimated expenditures for individual expenditure equations.[6] It is obvious in Table 3 that the R values associated with the approximate system are high on the whole. Nine of them greatly exceed 0.9, and the one for group 2, other cereals, is a little greater than 0.7. It is equally true for the R values of the two other systems. There is virtually no basis, in this regard, to choose among the three estimated systems.

The accuracy of demand prediction represents another measure of goodness of fit. It is designated as the ratio of estimated to actual quantities, which is equivalent to the ratio of estimated to actual expenditures. The results of the interpolation[7] and extrapolation[8] tests

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[5] Cross elasticities of demand are not necessarily symmetric, although cross elasticities of substitution are symmetric.

[6] The multiple correlation coefficients, R's, are presented to see the extent to which the estimated linear expenditure equations account for variation in expenditures. A. S. Goldberger and T. Gamaletsos [3] computed the R^2's as follows:

$$R_i^2 = 1 - \Sigma_t(\hat{v}_{it} - v_{it})^2/\Sigma_t(v_{it} - \overline{v}_i)^2 \quad (i = 1, \ldots, k),$$

where v_{it} indicates the expenditure of the ith commodity in the period t, $\hat{v}_{it}$ the estimated value of v_{it}, and $\overline{v}_i$ the sample mean of v_{it}. There is no guarantee, however, that the R^2's lie between 0 and 1. Hence the authors adopted the following formula, which is consistent with the above formula under classical least squares postulates:

$$r^2_{v_i\hat{v}_i} = (\Sigma_t[v_{it} - \overline{v}_i]\,[\hat{v}_{it} - \overline{\hat{v}}_i])^2/\Sigma_t(v_{it} - \overline{v}_i)^2 \cdot \Sigma(\hat{v}_{it} - \overline{\hat{v}}_i)^2.$$

[7] The interpolation test covers the whole period under investigation (1958–68) in this study. There are usually three kinds of interpolation tests—partial, total, and final. The test undertaken here represents a total test because the estimated linear expenditure equations are expressed in a reduced form.

[8] The extrapolation test is for 1959–70, the period other than that under immediate consideration (1958–68).

Table 3. Measures of goodness of fit for the approximate system, $\hat{x}_i/x_i$* and R

i Year	1	2	3	4	5	6	7	8	9	10
1958	1.04	.97	.96	.93	1.04	88	.94	.99	1.02	1.00
1959	1.01	1.01	.93	1.00	1.03	93	.96	.99	1.02	1.00
1960	.98	1.07	.95	1.02	1.02	.95	1.00	.99	1.01	1.01
1961	.98	1.04	.98	1.04	.99	.99	1.02	.99	.99	1.01
1962	.97	1.01	1.00	1.01	.99	1.05	1.11	1.01	.98	1.00
1963	.99	.99	1.06	1.00	.99	1.07	1.09	1.01	.98	1.00
1964	.98	.92	1.01	.99	.96	1.03	.97	1.03	1.00	1.01
1965	1.01	.94	1.06	.97	.95	1.08	.97	1.03	.99	1.00
1966	1.03	.97	1.00	.98	.97	.98	.97	1.03	1.00	1.00
1967	1.00	1.02	1.01	.99	1.01	1.02	.96	.99	1.00	1.00
1968	1.02	1.08	1.01	1.02	1.06	.97	1.02	.96	1.02	.99
1969	1.02	1.08	1.03	1.04	1.13	.97	1.02	.93	1.04	.99
1970	.96	1.07	1.02	1.05	1.23	1.01	1.02	.91	1.05	.98
R**	.98	.73	.98	.99	.98	.97	.98	.99	.99	.99

* x_i = actual quantity; $\hat{x}_i$ = estimated quantity.

** Multiple correlation coefficient for each fitted expenditure equation, measured as the simple correlation coefficient between actual and estimated expenditures.

for the approximate system are reported in Table 3. In the interpolation test for the period 1958–68, the measures lie within the range of 1 ± 0.12, which asserts an accuracy of more than 88 percent. The measures for other estimated systems exhibited that of greater than 89 percent accuracy. All three estimated systems are nearly equal in the accuracy of demand prediction and are successful only if they are intended to serve as a predictive model. In the extrapolation test for the period 1969–70, on the other hand, the measures fall within the limits of 1 ± 0.13 in 1969 and of 1 ± 0.23 in 1970. The accuracy of prediction goes down to 87 percent in 1969 and to 77 percent in 1970. The decrease in the predictive power of the authors' system is probably due to the recent decline in the annual growth rate of milk and egg consumption. Thus a static system has a limitation in demand projections.

Information inaccuracy is useful in assessing the accuracy of a demand system by a single measure. It takes a non-negative value: zero for a perfect prediction and a large value for a poor prediction. It was calculated to compare four different demand models, as seen in Tables 4 and 5. According to Table 4, Leser's system is the best in predicting the average budget shares of all commodity groups, because the average information inaccuracy is the lowest for the system. The naive model, on the other hand, is so high in average information inaccuracy that it is not suitable as a predictive model. The approximate system is higher than the other two systems in the same sense, but the difference between them is small. Table 5 presents the information inaccuracy of the four models by commodity group. Of all the models, the approximate system shows the lowest value for commodity groups 2, 8, and 9. The information inaccuracy of this system is relatively small for other commodity groups as well. Therefore, the approximate system can stand comparison with Leser's and Powell's systems from the standpoint of demand prediction.

Finally, a question will presumably arise as to whether the grouping of commodities is appropriate or not, because an expedient method was

Table 4. Information inaccuracy of $\hat{w}_i$ by year $I_t = \Sigma_i w_{it} \log w_{it}/\hat{w}_{it}$[a]

Year System	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average *I*
APS	461	249	196	97	191	260	152	292	85	21	216	202
LS	129	110	93	62	238	240	172	109	91	49	265	142
PS	269	114	90	60	249	292	127	278	120	20	288	173
NM[b]	—	8572	719	1474	1218	260	707	133	418	375	1354	1523

[a] Unit of measurement is 10^{-6} nat.

[b] NM = naive model ($\hat{w}_{it} = w_{i,t-1}$).

Table 5. Information inaccuracy of $\hat{w}_i$ by commodity group[a]

$$\bar{I}_i = \Sigma_t[w_{it} \log w_{it}/\hat{w}_{it} + (1 - w_{it}) \log (1 - w_{it})/(1 - \hat{w}_{it})]/T$$

i System	1	2	3	4	5	6	7	8	9	10
APS	23	21	30	5	19	62	25	9	15	12
LS	13	21	14	2	12	1	24	11	31	21
PS	29	25	30	2	13	54	33	10	18	11
NM[b]	404	34	10	23	117	48	25	19	796	195

[a] Unit of measurement is 10^{-6} nat.
[b] NM = naive model.

resorted to in this study. A principal component analysis of the residual correlation matrix may be used to answer such a question (see [10]). Residuals were calculated in quantity terms from the estimated expenditure equations. The correlation matrix of the standardized residuals for each system was factorized into principal components. The factor loadings of the principal components result in all commodity groups being aggregated into three categories in each system.

In the approximate system, the first category contains seven groups—other cereals, fish, meat, milk and eggs, vegetables, food consumed outside household, and other food—which are highly correlated with the first component. The second one involves rice and fruit, associated with the second component. The third one is non-food, explained by the third component. The same is true with Powell's system. The three largest components account for 92 percent of the total variance of the standardized residuals in the former system and for 93 percent in the latter system. Leser's system is somewhat different from the other two in the composition of the three categories of commodity groups. Within the first category of the approximate system, four groups—other cereals, meat, milk and eggs, and other food—are positively correlated with the first component. The rest are negatively correlated with the same component. In the second category rice and fruit have different signs for their factor loadings with respect to the corresponding component.

The commodity grouping undertaken in this study is not necessarily appropriate in the three cases. The additive preference assumption seems a little too severe to the authors' grouping of commodities.

Concluding Remarks

It is challenging to estimate a demand system for food commodities and commodity groups on a theoretical basis. In this paper, alternative versions of the linear expenditure system have been investigated with special reference to their theoretical features and to their effectiveness and limitations in empirical studies.

As the assumptions of Leser's and Powell's systems seem too restrictive to apply to subgroups of food commodities, a compromise between them is presented here for empirical application. It represents an approximation to Powell's system. The approximate system was empirically tested in comparison to the other two systems, with the result that it appears more acceptable than the others to derive a demand matrix for subgroups of food commodities. It was fitted to Japanese expenditure data for 1958–68. All income and price elasticities were derived straightforwardly from time-series data for 10 commodity groups including a broad category of non-food items.

The trend variable was so closely related to the income variable, an index of supernumerary income, that it was excluded from our specification of the linear expenditure system. Fortunately the multiple correlation coefficients as a whole are quite high in each system. Information inaccuracy is generally small for the three systems, as compared with the naive model.

In the interpolation test, the indicator of goodness of fit to the data was quite high, amounting to an accuracy of more than 88 percent. The indicator decreases noticeably in the extrapolation test, so that dynamic factors should be taken into account in specifying the demand system for a long-term analysis.

Strictly speaking, the linear expenditure system requires that all commodities be normal goods, substitutes by the conventional definition, and *gross* complements. In actuality, these conditions would not always be satisfied for subgroups of food commodities. Empirical results obtained in this study do not go beyond the confines of a statistical demand analysis. In order that demand analysis of food commodities may be argued on the utility basis, the underlying utility function must be of the type that embraces inferior goods as well as normal goods. Utility functions of such a type are needed to extend the present study toward scrutinizing the utility and demand structures in food consumption.

Furthermore, it would be very convenient if some criteria of practical use existed for aggregating individual commodities into homogeneous groups, or some simple procedures of distinguishing between different types of separabilities in empirical analyses.

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The Price Performance on the Futures Market of a Nonstorable Commodity: Live Beef Cattle*

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Cash cattle prices are found to be more accurate indicators of subsequent cash cattle price conditions than are the futures prices for distant contracts. This apparent relative inability of futures prices for live beef cattle to reflect later spot prices is becoming more pronounced over time.

Key words: **futures prices; cash prices; cattle; corn.**

CONTRACTS FOR COMMODITIES without storable inventories have now been traded actively on the commodities futures market since the mid-to-late 1960's, and the list of such commodities for which contracts are being written continues to expand. These developments have forced market participants and researchers to broaden their outlook, theories, and interpretations of various market aspects. Traditionally, the futures market has been thought of as a market which facilitates the temporal allocation of inventories, but the advent of contracts on nonstorable commodities has emphasized the forward pricing function of the futures market more than has previously been the case. It is the purpose of this note to examine the forward pricing function of one of the original and most successful contracts where no storable inventory is involved, live beef cattle.

Tomek and Gray [4] admirably launch an investigation into this general area by clarifying the stabilizing and allocative roles between commodities with continuous inventories (corn and soybeans) and a commodity with a discontinuous inventory (Maine potatoes). This note extends such an area of investigation by analyzing a commodity where the inventory changes in form in feedlots, and the production of the final product is continuous rather than just once a year.

Interpretation of futures prices has always been a matter of discussion. Working [5] contended 25 years ago that futures prices reflect a market-determined cash price plus a market-determined carrying charge, indicating an incentive to hold inventory for later delivery if the carrying charge is positive. He did not view futures prices as forecasts and argued that the futures market cannot act as both a forecasting agency and a medium for rational price information [6]. Nevertheless, futures prices are interpreted in most of the literature as reflecting the consensus of what traders expect the price to be at a given time in the future, given the information currently available. As new information emerges or events occur, futures and cash prices will be affected, but this does not imply the pre-existing prices were in error, only that they were based on different information than is subsequently available.

In a recent symposium, both Rockwell [2, p. 110] and Telser [3, p. 174] conclude from their research that futures prices are an "unbiased estimate" or the "market expectation" of ultimate spot prices. Tomek and Gray [4, pp. 373–374] argue that viewing the futures price as a reasonable forecast of subsequent cash prices is an extension of Working's notions, not a contradiction. They say, ". . . treating the price of a distant futures contract as part of a price of storage is not inconsistent with viewing the springtime prices of the harvesttime futures as a forecast of the forthcoming harvesttime price." They point out that "the price of the distant futures is a useful forecast in inventory-hedging markets." If it is a forecast in inventory-carrying markets, where both the inventory guidance and forward pricing roles are being performed, the futures price must also be a forecast in markets where the forward pricing role is emphasized. It is the efficiency with which this forward pricing function is performed that the author wishes to investigate here along with simply indicating what has been occurring in pricing relationships in the live beef cattle futures market.

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Table 1. Results of regressing closing futures prices on monthly futures prices up to eight months prior to delivery for corn and cattle

Months Prior to Delivery	Cattle[a]			Corn[b]		
	Intercept	Slope	r^2	Intercept	Slope	r^2
1	−1.98 (−.90)[c]	1.09 (13.78)	.85	4.07 (.37)	.976 (10.98)	.78
2	1.69 (.43)	.964 (6.70)	.57	17.16 (1.06)	.869 (6.74)	.76
3	6.42 (1.42)	.795 (4.82)	.41	31.70 (1.88)	.750 (5.62)	.49
4	10.32 (2.10)	.655 (3.64)	.28	54.01 (2.64)	.572* (3.53)	.27
5	14.36 (2.57)	.508* (2.49)	.16	61.69 (2.34)	.512* (2.46)	.15
6	17.18 (2.98)	.407* (1.92)	.10	89.28 (3.43)	.292* (1.42)	.06
7	19.50 (3.01)	.320* (1.35)	.05	102.97 (4.04)	.184* (.91)	.02
8	21.04 (3.25)	.265* (1.12)	.04	114.47 (4.48)	.092* (.46)	.01

[a] Thirty-six contracts maturing from April 1965 through February 1971.

[b] Thirty-five contracts maturing in 1964 through 1970.

[c] Coefficients in parentheses are t-ratios.

* Significantly different from 1.0 at the 95 percent level of confidence.

Empirical Investigation

Model I—An explicit method of determining the ability of futures prices to estimate subsequent cash prices is with the following simple model:

$$FP_t = a + b\, FP_{t-i}$$

where FP_t is the closing futures price for a contract at delivery[1] and FP_{t-i} reflects the futures price for the ith month before maturity. If FP_{t-i} is an accurate forecast of FP_t, then the intercept will be zero and the slope unity. Of course, as i becomes larger, or as one gets further away from maturity, less accurate results might be expected since less information concerning conditions at delivery time is available. Delivery in this study was assumed to be the day prior to the last day of trading for a contract.

To test this model, prices for the first 36 live beef cattle contracts as traded on the Chicago Mercantile Exchange, with maturity dates of April 1965 through February 1971, were used in the analysis.[2] For comparison the same model was used to test the ability of corn futures prices to reflect subsequent cash prices. Thirty-five corn contracts during the approximate same time period as traded on the Chicago Board of Trade with maturity dates in 1964 through 1970 were used for these regressions.[3]

Table 1 presents the regression results for each of eight lagged months prior to delivery for both cattle and corn. As expected, the results for cattle show that the closer to the maturity date, the more accurately the futures price reflects final closing price. The intercept is not significantly different from zero for the first three lagged months, but is for the last five. The slope coefficient is not significantly different from one, as suggested by the theoretical model, for the first four lagged months, but is significantly different for the last four.

Do the cattle futures prices reflect subsequent spot prices efficiently or not? One way of judging this point is to compare these results with similar tests on a commodity like corn where the relevant theories are well-established. Interestingly, the results for corn show a pattern very similar to cattle. The intercept is significant or not in the same months as was the case for cattle, and the determination of the significance of the slope coefficient differs from the cattle results only in the fourth lagged month. The coefficients of determination are of similar magnitude and decrease as the time lags increase.

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[1] It was found that there is little empirical difference whether the futures price or the cash price at delivery is used in the regression analysis.

[2] The choice of these contracts is discussed later in the paper.

[3] All futures prices were obtained from the annual yearbooks of the Chicago Mercantile Exchange (cattle) and the Chicago Board of Trade (corn). Weekly prices used in this note are represented by the Friday close, while the monthly prices referred to here are represented by the close on the 15th day of the month or nearest day if the 15th fell on a weekend. It was found that the analysis in this study was not sensitive to whether average prices or a representative price for each time period was used.

Thus the above model shows remarkable similarity in the forward pricing efficiency of the cattle and corn futures contracts. Such a similarity might seem surprising since the two commodities have some distinct characteristic differences as previously noted. However, a second model will give us further insight as to the forward pricing efficiency of the cattle contracts.

Model II—As argued above, in the economics of futures trading the futures price is expected to reflect a consensus of present expectations of what the cash price will be at some particular date in the future (in Chicago). The difference between the futures price and the present cash price is the basis, and as delivery time approaches, this basis will get smaller until it theoretically equals zero at the time of contract maturity. Since changes in the size of the basis will be small relative to changes in price levels, the present cash price ought to yield an approximation of the future cash price almost as accurately as the futures price. As Tomek and Gray [4, p. 373] state, ". . . at least in circumstances involving continuous inventories, forecasts are reflected just as much in cash and nearby futures as in distant futures prices. The element of expectations is imparted to the whole temporal constellation of price quotations, and futures prices reflect essentially no prophecy that is not reflected in the cash price and is in that sense already fulfilled."

It is generally agreed that for commodities such as cattle with no storable inventory, there need not be as close an intertemporal relationship between the current cash price and the futures price, particularly for distant futures contracts, as in the case for grains. The closest relationship for cattle ought to occur between feeder cattle prices and futures prices [1]. It is known that there are some intertemporal relationships between cash and futures prices for cattle because feeder and fed steer prices are related due to expectations imparted in the market, and cash and futures prices must come together at delivery and will be similarly influenced by new information. However, one would not expect cash prices of nonstorable commodities to indicate subsequent cash prices as accurately as futures prices, especially for distant futures.

To analyze the above hypotheses and gain more information about the efficiency of futures prices in indicating the final cash price, a mean square error coefficient was computed on weekly corn and cattle prices. The mean square error (*MSE*), sometimes called a quadratic loss function, was computed on the difference between the price at delivery and the corresponding price j weeks prior to maturity, j ranging from 1 to 36. The formula is:

$$MSE_j = \frac{1}{n} \sum_{i=1}^{n} (P_{i,t} - P_{i,t-j})^2 \quad \begin{matrix} i = 1, \ldots, n \\ j = 1, \ldots, 36. \end{matrix}$$

The *MSE* was initially computed for the futures prices and corresponding cash prices for the 35 corn contracts[4] to test the above quotation from Tomek and Gray and to provide a basis for comparison with the cattle contracts. The plot in Figure 1 shows the *MSE* getting larger, as expected, the further away it is from delivery. More importantly, the *MSE*'s for cash and futures are very close together over the entire range, indicating each is about equally efficient in approximating the future cash price and confirming the above quote.

Next, the weekly *MSE*'s were computed for the cattle futures prices over the first 36 contracts. For comparison and to gain information on forward pricing efficiency, the *MSE*'s for corresponding cash prices were also computed.[5] Figure 2 demonstrates that the *MSE*'s for both series get larger at the same rate back to about the 15th week prior to delivery. Then the *MSE* for futures prices continues to increase at a rapid rate while the *MSE* for cash prices increases at a very slow rate. This would indicate that from about 15 to 36 weeks prior to delivery, one can expect a better estimate of the future cash price of cattle by looking at the present cash price than by studying the futures price itself. This is contrary to theoretical expectations and to the above discussion.

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[4] Cash prices are the mid-point of the price range for number 2 yellow corn, Chicago, on Fridays as reported in the annual yearbooks of the Chicago Board of Trade. The results are presented in the Appendix Table.

[5] Cash prices are the average price of all steers sold in Chicago on Fridays as provided privately to the author by the USDA Market News Service, Chicago. Omaha prices used in this paper are the weekly average price of choice steers, 1,100 to 1,300 pounds in Omaha as reported publicly. The results are presented in the Appendix Table.

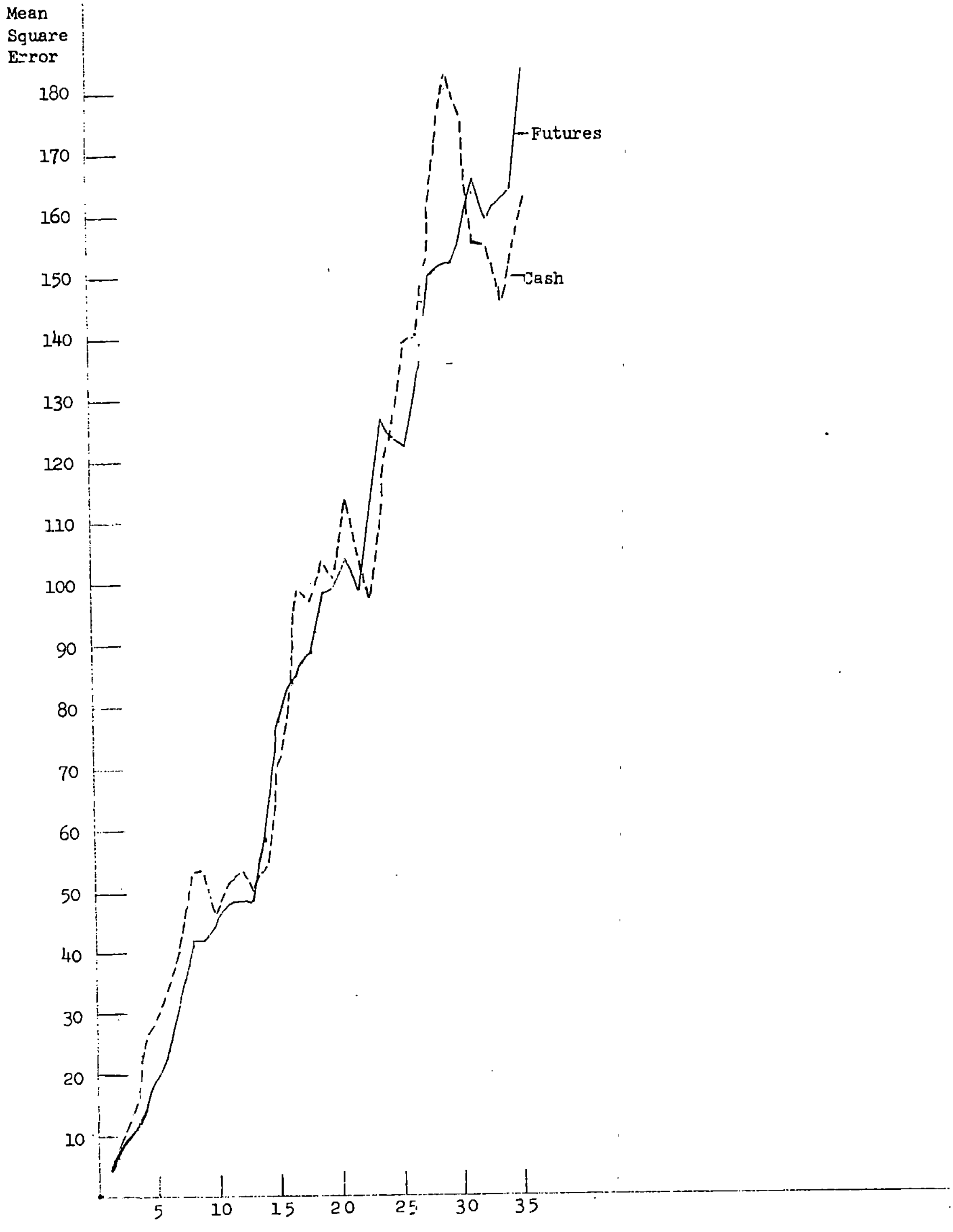

Figure 1. Mean square error of corn futures prices and corresponding cash prices from 1 to 36 weeks prior to contract delivery for 35 contracts

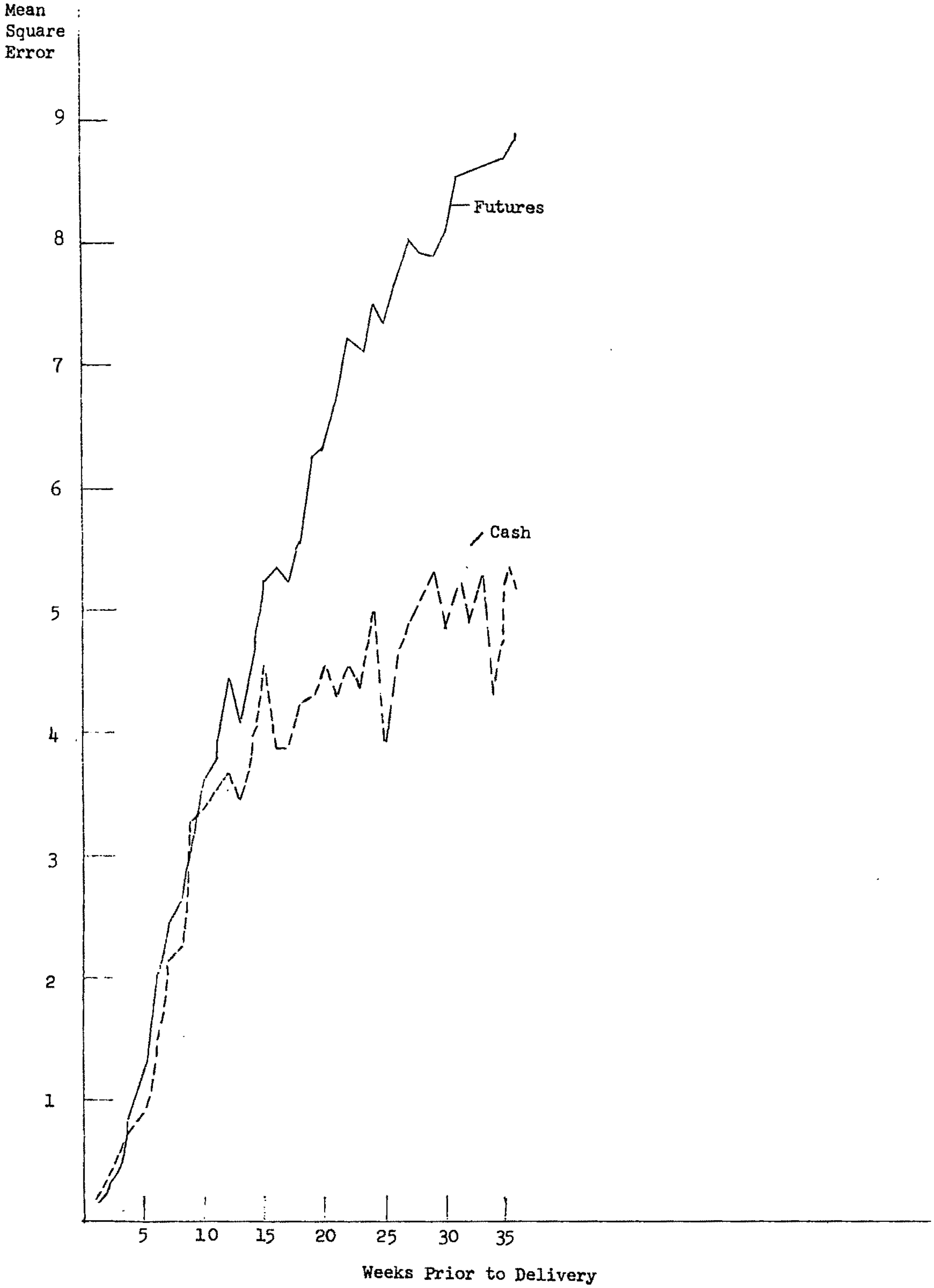

Figure 2. Mean square error of cattle futures prices and corresponding cash prices from 1 to 36 weeks prior to contract delivery for first 36 contracts

Taking the square root of the *MSE* for corn and the *MSE* for cattle and adjusting these according to price level (called a coefficient of stability[6]) generates coefficients of similar magnitude for the two commodities, as might be expected given the previous results of Model I. The exception is that cash cattle prices demonstrate more stability than the other price series for the more distant weeks prior to delivery.

The discovery that cash prices for cattle have smaller *MSE*'s than futures prices raises some interesting possibilities. It might be characteristic of new markets to have inaccurate price estimates until participants become accustomed to the price movements and relationships and until sizable hedging use develops. To test this, the 36 cattle contracts thus far analyzed were divided into two groups—the first 18 contracts and the last 18 contracts. At the same time the next 12 and most recent contracts (April 1971–February 1973) were combined into a third separate group.

Respective cash and futures *MSE*'s for each group were computed and are shown in Figure 3. Two distinct features are noticeable: (1) for each group the *MSE* for cash price is less than the respective *MSE* for futures price from the 15th to the 36th week prior to delivery; (2) the *MSE*'s get progressively larger for the more recent contracts. Thus, the surprising relationship that cash prices generate smaller *MSE*'s than the respective futures prices has not changed over time and, in fact, the absolute and relative differences between the two sets of *MSE* get larger with the more recent contracts. The ability of the futures prices to anticipate subsequent cash prices appears to be less efficient as time progresses. The fact that the cattle market has recently become more volatile explains in part this lower efficiency over time, but it does not explain the decreasing of efficiency of the futures price relative to the cash price.[7] A study of the respective coefficients of stability revealed similar relationships, so higher cattle price levels are not the explanation.

The above findings suggest that the prices of cattle actually change less than the futures market anticipates or that futures prices underestimate and overestimate swings in cattle prices. Detailed analysis on the first 36 contracts seems to confirm this, but when the next 12 most recent contracts are included, the picture changes. Because of the recent dramatic rise in cattle prices, the most recent contracts underestimate subsequent spot prices by such a great amount that it appears on average that futures and cash prices underestimate subsequent cash prices regardless of how contracts are grouped.

Conclusions and Implications

It appears that futures prices for live beef cattle estimate subsequent spot prices as efficiently as do corn futures prices, despite the obvious differences between the two commodities with respect to inventories and production. Although the purpose here was to use the analysis on corn only for comparison, the author found nothing that would contradict the findings and conclusions of Tomek and Gray [4]. However, a direct comparison with their results is not possible since they looked at only the one contract immediately after harvest over a period of years.

Further evaluation of live beef cattle price relationships revealed that for distant futures, the cash price is a more accurate indicator of future cash price conditions than is the futures price. Also, the futures price becomes less and less efficient both absolutely and relative to the cash price estimates. In other words, the cash price is more stable than the futures price for distant contracts. These facts suggest some ramifications.

The producer who looks at the futures prices routinely to establish a feeding margin so that he can decide whether or not to purchase and feed cattle may receive false signals and be misled into a costly decision, either a money loss or foregone profits. The producer would apparently receive better guidance from studying the present cash price situation. Consequently, for feeders who contract, it may be more rational for them to use contracts where the cash price rather than the futures price is used as the basis for determining sale values. Such actions are common, and investigations by the author revealed little evidence that feeders pay much

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[6] This coefficient is related to Theil's U coefficient. The latter differs by having the square root of the average squared price in the denominator instead of the average price.

[7] These increases in price fluctuations explain why the most recent contracts were omitted from the previously discussed regressions. It was felt that the data of the comparable period used for both the corn and cattle regressions were relatively free from external shocks. Also, the most recent 12 contracts were excluded from the data used to generate Figure 2 because of the need to change from Chicago to Omaha for cash prices.

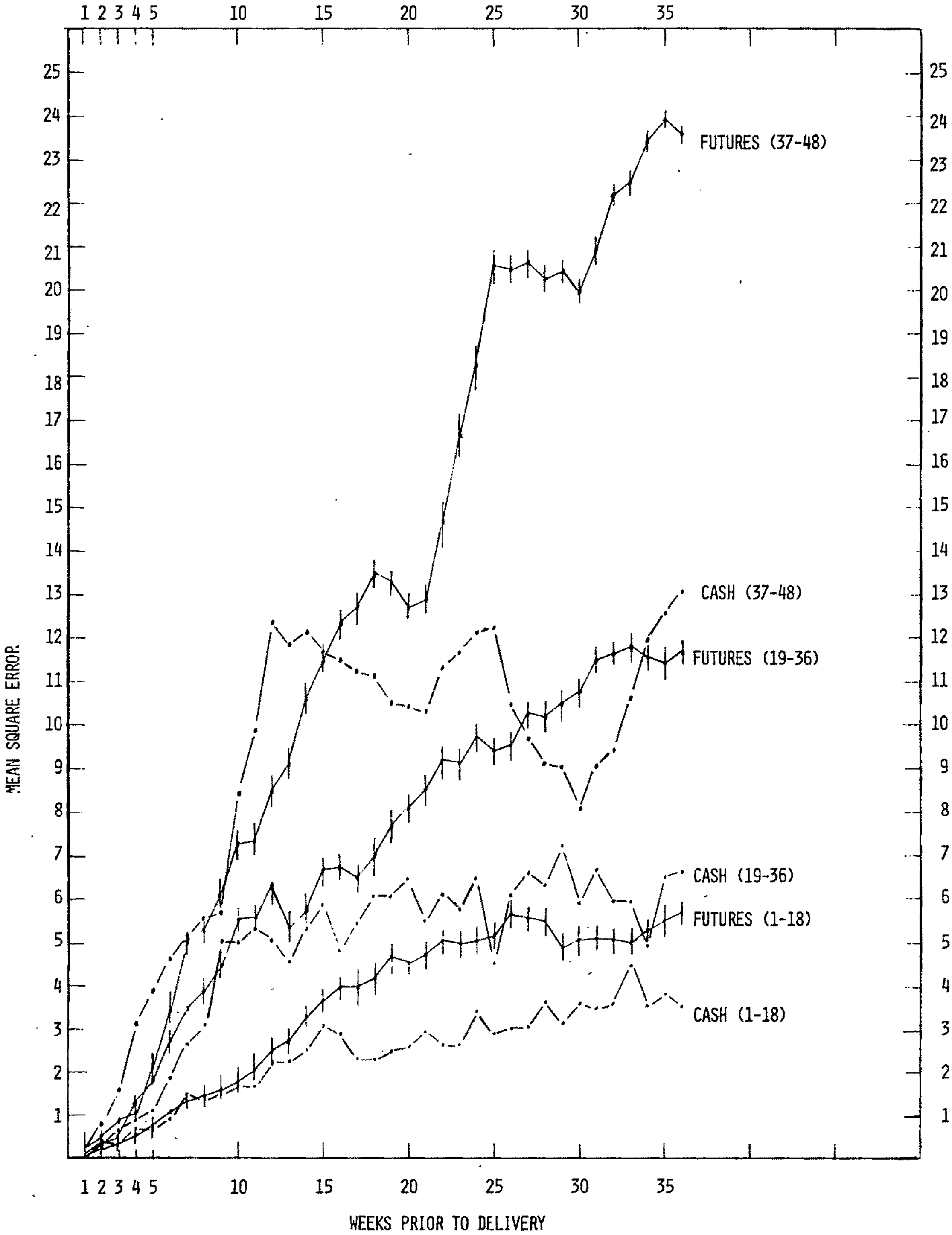

Figure 3. Mean square error of cattle futures prices and corresponding cash prices from 1 to 36 weeks prior to contract delivery for first 48 contracts divided into three groups

attention to the forward cattle futures market when buying feeder stock.

The fact that the dividing point in the price relationships observed occurs consistently about the 15th week prior to delivery may be an indication of little or no hedging longer than about four months duration, about the length of time many stock are in feedlots. The analysis presented in this note does not lend itself to a systematic evaluation of routine hedging and stability in producer revenue as in [4], but it seems unlikely that hedges longer than four months' duration could stabilize revenues.

Hence, while the futures market may not exist to predict prices, but to act as a mechanism for passing on risks in price level changes, it is possible that the market can be destabilizing and can misdirect the allocation of resources. Exactly why the market appears to do an inefficient job of forward pricing relative to cash prices remains puzzling and will take further research. A main problem has been the lack of a sound theoretical base concerning cash-futures price relationships of nonstorable commodities that could be used as a guide in empirical investigations. Findings here and elsewhere should encourage work in that direction.

Research is needed to answer questions such as the following: do the relationships discovered here occur with all nonstorable commodities or just characteristically with cattle? Perhaps it is only a characteristic of this particular set of data, and nonstorability is irrelevant. Could a thin market be the explanation or, in other words, is there a lack of sufficient hedging or forward pricing to create price relationships consistent with those theories that are presently understood? Finally, are these relationships due to a relative lack of trade participation, or possible excessive speculation? There are several issues about the livestock futures market which are not yet well understood.

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APPENDIX

Appendix Table. **Mean square errors (MSE_j) for cash and futures prices, corn and live beef cattle, various periods**

			Live Beef Cattle[c]							
j	Corn[a] (n = 35)[b]		Periods 1 & 2 (n = 36)[d]		Period 1 (n = 18)[e]		Period 2 (n = 18)[f]		Period 3 (n = 12)[g]	
(Weeks)	Cash	Futures	Cash	Futures	Cash	Futures	Cash	Futures	Cash	Futures
1	4.35	4.59	.143	.132	.182	.112	.103	.151	.255	.251
2	9.14	9.07	.340	.297	.399	.250	.279	.343	.801	.306
3	14.12	11.07	.535	.473	.382	.395	.688	.550	1.566	.872
4	25.59	15.17	.797	.971	.669	.586	.924	1.355	3.167	1.048
5	29.35	20.03	.914	1.286	.683	.773	1.144	1.798	3.923	2.146
6	34.82	24.84	1.439	1.925	.961	1.069	1.915	2.780	4.648	3.421
7	42.13	33.24	2.105	2.442	1.472	1.368	2.738	3.515	5.185	5.023
8	53.42	42.04	2.235	2.623	1.356	1.419	3.113	3.825	5.646	5.275
9	53.40	42.27	3.274	3.069	1.497	1.596	5.050	4.542	5.737	6.061
10	46.83	45.20	3.369	3.637	1.726	1.760	5.012	5.514	8.444	7.284
11	51.31	48.18	3.531	3.800	1.675	2.013	5.386	5.585	9.871	7.347
12	53.41	48.67	3.672	4.455	2.229	2.547	5.113	6.361	12.419	8.468
13	50.49	48.48	3.432	4.062	2.286	2.741	4.577	5.381	11.843	9.147
14	53.56	58.62	3.933	4.511	2.476	3.274	5.389	5.748	12.199	10.595
15	67.99	74.84	4.522	5.220	3.138	3.744	5.906	6.696	11.660	11.505
16	79.03	82.48	3.880	5.352	2.928	3.955	4.830	6.748	11.491	12.367
17	99.17	85.28	3.879	5.209	2.324	3.943	5.433	6.473	11.221	12.721
18[h]	97.33	89.47	4.233	5.581	2.326	4.182	6.144	6.978	11.154	13.564
20	101.25	99.55	4.569	6.350	2.603	4.565	6.534	8.137	10.438	12.724
22	105.80	98.92	4.559	7.213	2.845	5.063	6.177	9.243	11.367	14.699
24	114.77	126.73	5.038	7.505	3.420	5.088	6.565	9.787	12.149	18.301
26	139.37	122.29	4.646	7.680	3.059	5.689	6.144	9.559	10.507	20.494
28	154.38	150.37	5.023	7.914	3.629	5.498	6.339	10.195	9.157	20.361
30	184.07	152.21	4.825	8.092	3.601	5.064	5.912	10.782	8.131	19.938
32	156.71	166.01	4.871	8.566	3.633	5.079	5.971	11.664	9.448	22.218
34	144.79	161.99	4.267	8.634	3.533	5.312	4.918	11.586	11.989	23.465
36	162.94	183.71	5.189	8.889	3.561	5.729	6.635	11.697	13.133	23.618

[a] Delivery months for corn are March, May, July, September, and December.

[b] Includes all the contracts delivering in 1964 through 1970.

[c] Delivery months for cattle are February, April, June, August, October, and December.

[d] Includes all the contracts delivering from April 1965 through February 1971.

[e] Includes all the contracts delivering from April 1965 through February 1968.

[f] Includes all the contracts delivering from April 1968 through February 1971.

[g] Includes all the contracts delivering from April 1971 through February 1973.

[h] Odd numbered values of j from 19 and on are omitted to save space.

Market Intermediaries and Price Instability: Some Welfare Implications*

JURG BIERI AND ANDREW SCHMITZ

The welfare consequences of price instability critically depend on the type of market intermediary. Both a producer marketing board and a pure middleman will stabilize consumer prices; but the latter, unlike the producer marketing board, will find it advantageous to "manufacture" price instability for producers.

Key words: **price instability; welfare; market intermediaries.**

I

PRICE INSTABILITY and its consequences have occupied an important part of economic theory and policy formulation. Very early, Waugh [12] demonstrated that consumers could benefit from price instability. Later, Oi [8] showed that producers could gain also. Massell [7] integrated these results for a closed model and concluded that with *actual compensation* both producers and consumers preferred price stability. Samuelson [10] also demonstrated that society could not ". . . lift its welfare by its own bootstraps through manufactured instability." Recently, Hueth and Schmitz [4] and Bieri and Schmitz [1] considered the effects of price instability in an international trading framework and demonstrated that the welfare consequences of price instability critically depended on the source of the instability and the degree of tariff protection.

It seems unfortunate that the work to date on price instability has been based largely on the assumption of perfectly competitive markets. As a result, a major shortcoming is that the role played by market intermediaries (operating outside the perfectly competitive environment) in formulating prices is not considered. Examples of questions one might ask are the following: (1) Are the results based on perfectly competitive markets affected when noncompetitive markets are assumed? (2) Do the welfare effects of price instability depend on the *type* of market intermediary that is in existence? (3) Is it advantageous for a market intermediary, by storing, to stabilize consumer prices but not producer prices? To illustrate the case for competitive markets, consider one of Massell's situations where instability is created by shifts in supply. In Figure 1 the two unstable prices are P_1 and P_2, and it is assumed that each occurs with a .5 probability. Through a buffer stock, prices can be stabilized at P_u; consumers gain the crosshatched area from price instability.[1] It is clear, however, that producers prefer price stability. Overall, society prefers price stability, and the net gain is represented by the two areas *abc* and *cde*.

The purpose of this paper is to consider the welfare implications of price instability when markets are noncompetitive and to attempt to answer the type of questions raised above. Many products are bought and sold by intermediaries (e.g., marketing boards and private traders). It seems unrealistic to assume that in many cases the strictly competitive market structure exists throughout the market channel. As Kaldor [5, pp. 1247–48] has recently pointed out in his attack on the existence of equilibrium economics without intermediaries:

> In a state of equilibrium, production and consumption, or 'flow'-demand and 'flow'-supply, are necessarily equal in each market, and in the rarefied world of Walrasian perfection where markets are *continually* in equilibrium, the question of how the market responds to 'disequilibria' does not arise because all such 'disequilibria' are ruled out—all equilibrating adjustments are assumed to be instantaneous, either because changes are timeless or because all changes have been perfectly foreseen.
>
> However, the markets of the real world are not in continuous equilibrium in this sense; there are, or can be, persistent differences between production and consumption which are reflected in increments or decrements in stocks. The impact effect of any undesigned or unex-

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[1] The majority of these types of models have been based on the concept of economic surplus. This topic has recently been surveyed by Currie, Murphy, and Schmitz [3].

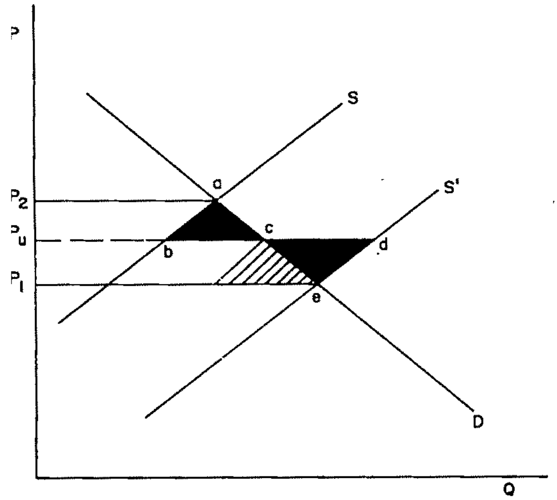

Figure 1. Price instability in a perfectly competitive market

> pected rise in production (due to a bumper harvest, for example) must be a rise in stocks; any subsequent adjustments in flow-demand or supply due to consequential price changes require time to materialize. For that reason, competitive markets are inconceivable without intermediaries—merchants, or 'dealers'—who are both buyers and sellers at the same time (at different prices), and who carry stocks so as to make 'a market' that enables producers to sell and consumers to buy.

Kaldor [5, p. 1248] says further on the importance of the middlemen, ". . . the merchants [*sic*] function, in other words, is to create and preserve an 'orderly' market which they can do only through their willingness to act as a shock absorber. . . ."

In the following models Kaldor's analysis is taken one step further, for it is shown that the welfare effects of price instability critically depend on the market structure of the intermediaries which perform the marketing function. Two intermediaries representing different market structures and labeled as pure middlemen and producer marketing boards are considered. An assumed difference in their objectives is that a pure middleman (*PM*) is interested in maximizing profits by behaving as a monopolist *and* a monopsonist, while a producer marketing board (*PMB*) maximizes producer returns by behaving as a monopolist only.[2]

II

Before it is demonstrated, for example, that pure middlemen do not necessarily want to stabilize producer prices whereas—if the good can be stored—a *PMB* will maximize producer returns by stabilizing prices, a framework for considering a marketing board is briefly discussed. A model incorporating a *PM* seems to be straightforward since one can reasonably assume that the objective is to maximize profits. However, the *PMB* is assumed to maximize producer returns; thus it is interested in the size of both profits *and* producers' surplus. In Figure 2, a perfectly competitive market price would be P_f, and $0Q_2$ of the good would be produced.[3] However, a *PMB* interested in maximizing producer returns would restrict quantity to $0Q_1$ (e.g., by a producer quota) and charge price P_b. Thus, with a *PMB* as opposed to a perfectly competitive market, producers gain P_bdbc in profits but lose P_fabc in producers' surplus. It can be shown algebraically that area P_bdeP_f is greater than *eab*. Thus in the following discussion the producer returns maximized by a *PMB* are defined as the total value of quantity sold minus costs of production and storage plus the producers' surplus (i.e., $P_bdQ_10 - bc0Q_1 + bcg$ in Fig. 2).

At this point it should be noted that a *PM* does not maximize profits in the manner that a *PMB* maximizes producer returns. Rather, a *PM* would equate the marginal schedule *MC* to the marginal revenue schedule in order to determine price. It can be shown mathematically that a *PM* would charge price P_m while a *PMB* would charge price P_b.

III

The equilibrium quantities and prices for the cases of *PM*'s and *PMB*'s as intermediaries are investigated with the assumption, as in the previous studies, of linear demand and supply schedules and two periods over which decisions are made. The supply function in the first period

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[2] Actual middlemen or marketing boards clearly may not behave in the postulated fashion as one reviewer pointed out. We simply use these terms to label two types of market intermediaries. Other models, for example, could include cases of intermediaries which maximize consumer welfare which could similarly be labeled consumer cooperatives even though actual cooperatives may act differently. How specific intermediaries act in the marketplace is an empirical question and is not dealt with in this paper.

[3] The supply schedule *S* is a perfectly competitive industry supply schedule obtained by summing each of the individual firm's short-run marginal cost curves. Similarly, the *MC* curve is a monopsonist's marginal cost curve (marginal outlay curve).

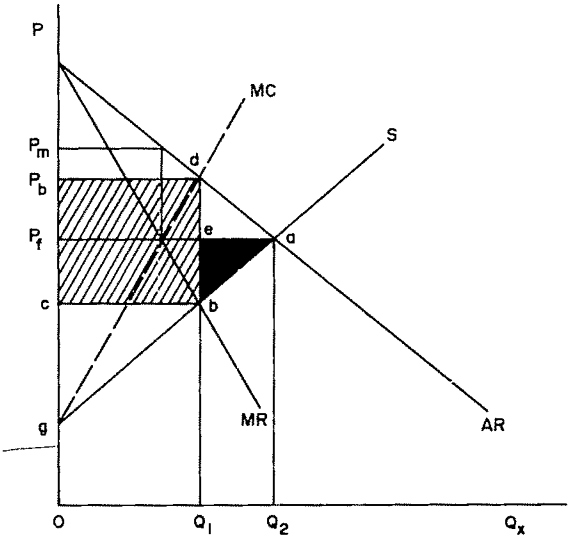

Figure 2. A simple marketing board model

is assumed to be below the one for the second period, thus allowing for the possibility of storage. Algebraic expressions for all the schedules used are given first, and the equilibrium values for the quantities and prices involved are presented afterward.

The two supply schedules are expressed as

$$p_{s1} = \alpha a + \beta b q_{s1}; \quad a, b > 0; \quad 0 < \alpha, \beta < 1;$$
$$p_{s2} = a + b q_{s2}$$

where q_{s1}, q_{s2} are the quantities supplied and p_{s1}, p_{s2} are their corresponding prices.

The demand schedules are similarly defined for the two periods:

$$p_{d1} = \gamma c - \delta d q_{d1}; \quad c, d, \gamma, \delta > 0;$$
$$p_{d2} = c - d q_{d2}$$

where q_{d1}, q_{d2} are the quantities demanded and p_{d1}, p_{d2} are the corresponding prices.

Furthermore, a simple storage cost function is introduced:

$$s.c. = g(q_{s1} - q_{d1}),$$

and the market clearing equation is[4]

$$q_{s1} + q_{s2} = q_{d1} + q_{d2}.$$

The *PM* maximizes profits (π) over the two periods. Profit is expressed as:

$$\pi = \gamma c q_{d1} - \delta d q_{d1}^2 + c q_{d2} - d q_{d2}^2 - \alpha a q_{s1}$$
$$- \beta b q_{s1}^2 - a q_{s2} - b q_{s2}^2 - g(q_{s1} - q_{d1}).$$

Maximizing this function subject to the market clearing equation results in the following equilibrium expressions:

$$q_{d1}^{\pi} = \frac{1}{2\delta d}(\gamma c - s' + r'g);$$
$$q_{s1}^{\pi} = \frac{1}{2\beta b}(s' - r'g - \alpha a);$$

$$p_{d1}^{\pi} = \frac{1}{2}(\gamma c + s' - r'g);$$
$$p_{s1}^{\pi} = \frac{1}{2}(\alpha a + s' - r'g);$$

$$q_{d2}^{\pi} = \frac{1}{2d}(c - s' - t'g);$$
$$q_{s2}^{\pi} = \frac{1}{2b}(s' + t'g - a);$$

$$p_{d2}^{\pi} = \frac{1}{2}(c + s' + t'g);$$
$$p_{s2}^{\pi} = \frac{1}{2}(a + s' + t'g)$$

where the superscript π refers to the profit maximization, and

$$s' = \frac{\beta b(\gamma + \delta)\, c + \delta d(\alpha + \beta)\, a}{\beta b(1 + \delta) + \delta d(1 + \beta)}$$
$$r' = \frac{\beta\delta(b + d)}{\beta b(1 + \delta) + \delta d(1 + \beta)};$$
$$t' = \frac{\beta b + \delta d}{\beta b(1 + \delta) + \delta d(1 + \beta)}.$$

The *PMB* maximizes returns (R) to the producers over the two periods. Returns are:

$$R = \gamma c q_{d1} - \delta d q_{d1}^2 + c q_{d2} - d q_{d2}^2 - \alpha a q_{s1}$$
$$- \frac{1}{2}\beta b q_{s1}^2 - a q_{s2} - \frac{1}{2} b q_{s2}^2 - g(q_{s1} - q_{d1}).$$

Equilibrium values for the different quantities and prices resulting from maximization of R subject to the market clearing equation are:

$$q_{d1}^{R} = \frac{1}{2\delta d}(\gamma c - s + rg);$$
$$q_{s1}^{R} = \frac{1}{\beta b}(s - rg - \alpha a);$$

$$p_{d1}^{R} = \frac{1}{2}(\gamma c + s - rg);$$
$$p_{s1}^{R} = s - rg;$$

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[4] Throughout the development, it will be assumed that the parameters of the different functions used are such that nonnegative equilibrium prices and quantities result.

$$q_{d2}{}^{R} = \frac{1}{2d}(c - s - tg);$$

$$q_{d2}{}^{R} = \frac{1}{b}(s + tg - a);$$

$$p_{d2}{}^{R} = \frac{1}{2}(c + s + tg);$$

$$p_{s2}{}^{R} = s + tg$$

where the superscript R refers to the returns maximization, and

$$s = \frac{\beta b(\gamma + \delta)\, c + 2\delta d(\alpha + \beta)\, a}{\beta b(1 + \delta) + 2\delta d(1 + \beta)}$$

$$r = \frac{\beta\delta(b + 2d)}{\beta b(1 + \delta) + 2\delta d(1 + \beta)};$$

$$t = \frac{\beta b + 2\delta d}{\beta b(1 + \delta) + 2\delta d(1 + \beta)}.$$

Some interesting special cases emerge from the above results.

Assume (as did the previous studies) that there are no storage costs (i.e., $g = 0$). This results in stable producer prices when a *PMB* is present, i.e., $p_{s1}{}^{R} = p_{s2}{}^{R}$. However, note that this is not the case when a *PM* does the trading, i.e., $p_{s1}{}^{\pi} \neq p_{s2}{}^{\pi}$.

If one also prevents the demand from shifting ($\gamma = \delta = 1$), the quantities (and corresponding prices) demanded are equal for both periods regardless of whether a *PM* or a *PMB* is the actor, i.e., $q_{d1}{}^{\pi} = q_{d2}{}^{\pi}$ and $q_{d1}{}^{R} = q_{d2}{}^{R}$.[5]

Again, if the assumption of no storage cost is made and only the demand schedule shifts rather than the supply schedule ($\alpha = \beta = 1$), the quantities produced in both periods are the same regardless of the market agent, i.e., $q_{s1}{}^{\pi} = q_{s2}{}^{\pi}$ and $q_{s1}{}^{R} = q_{s2}{}^{R}$.[6]

IV

In this section two of the more interesting results derived above are shown geometrically.[7] Figure 3 deals with a *PM* where instability is due to shifts in supply, while Figure 4 considers the same source of instability but a *PMB* does the trading.

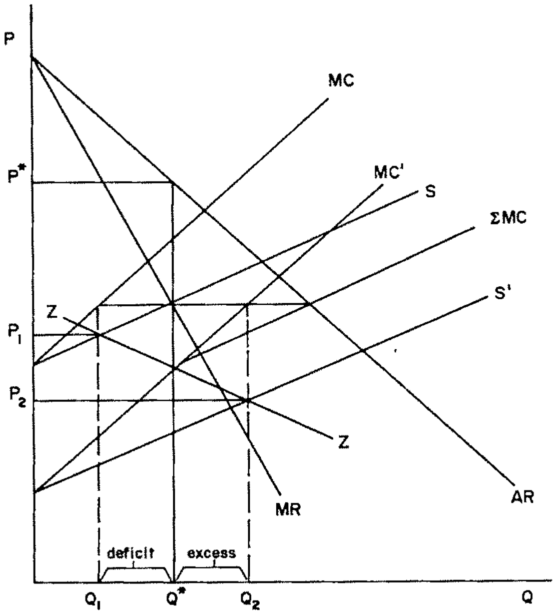

Figure 3. **Price instability: the pure middleman case**

Consider a market where *AR* is the average revenue curve and *MR* is the corresponding marginal revenue schedule. For a two-period analysis, *AR* is also the sum of the marginal revenue schedules. A *PM* will maximize profits over the two periods by charging price *P** in

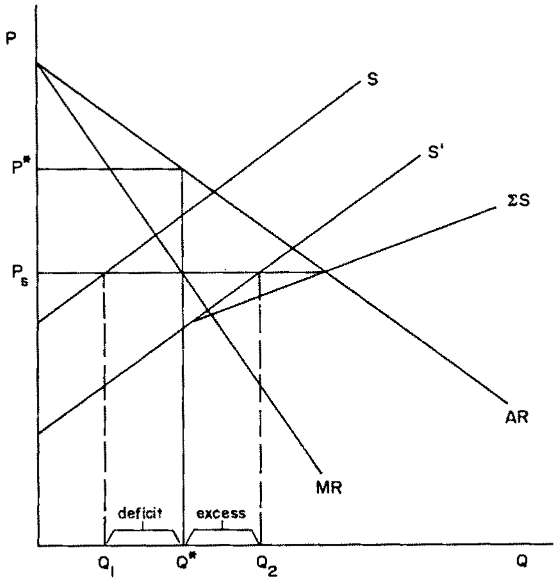

Figure 4. **Price instability: the producer marketing board case**

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[5] It should be noted that the *PM* can still act as a discriminating monopsonist, i.e., $p_{s1}{}^{\pi} \neq p_{s2}{}^{\pi}$ unless, in addition, the supply schedule simply pivots ($\alpha = 1$). The *PMB* never does act as monopsonist.

[6] In this case both the *PM* and the *PMB* act as discriminating monopolists unless the demand schedule simply pivots ($\gamma = 1$). In that case no discrimination is profitable and, thus, $p_{d1}{}^{\pi} = p_{d2}{}^{\pi}$ and $p_{d1}{}^{R} = p_{d2}{}^{R}$.

[7] As in previous theoretical discussions on price instability, it is due to supply shifts *or* shifts in demand—not both.

each period (thus the *PM* will stabilize prices on the demand side) and pay producers P_1 for Q_1 in one period and P_2 for Q_2 in the other period. Part of Q_2 will be stored in that period. Through storage, prices are stabilized to consumers, but note that producer prices are not! A *PM* finds it to his advantage not to stabilize producer prices even though he does store part of the good produced.

Consider now the producer marketing board case in Figure 4. A *PMB* would equate the sum of the marginal revenue schedules (which is the *AR* schedule) with the sum of the supply schedules (denoted as ΣS). A *PMB* would stabilize consumer prices at P^*. However, note that, unlike the *PM* case, to maximize producer returns a *PMB* would also stabilize producer prices. The producer would receive price P_s in both periods. The *PMB* would store part of Q_2 in that period.

It is clear that with a *PMB* not only are consumer prices lower than if a *PM* does the trading, but also producer prices are stabilized (a reason often given for the existence of producer marketing boards). Also, producer returns are increased since a *PMB,* unlike the *PM,* does not act as a monopsonist.[8]

To this point a distinction has not been made as to whether instability is exogenous (e.g., caused by weather) or is "manufactured." As Samuelson [10] pointed out, instability need not be due only to natural causes but can be manufactured; in neither case does society (as previous studies have shown) benefit from price instability. The focus here, however, is not with society only, but with the motives of an intermediary acting in a single market. If price instability is exogenous, the *PM* gains from storing, acting as a monopolist, and acting as a monopsonist. However, if instability is not caused by natural forces, the models suggest that it would actually pay a *PM* to manufacture instability at the expense of the rest of society. As an example, one can visualize cases which involve contracts where all-or-none offers are made to producers. With reference to Figure 3, such prices and quantities are P_1Q_1 and P_2Q_2. Joining a line through the corresponding points represents a downward sloping schedule labeled *ZZ*. However, it is important to note that the schedule *ZZ* is not a supply schedule—it merely represents the all-or-none offers made over time by *PM*'s to producers.[9]

V

The authors have presented some of the welfare implications when price instability occurs in noncompetitive markets. The type of intermediary in the market was made explicit; trading was assumed to take place by either a producer marketing board or a pure middleman. In many countries marketing boards exist for trading their major agricultural products (e.g., the Canadian Wheat Board and the Australian Wool Board). They have several functions among which are to provide price stability to producers and to eliminate excess profits which can be obtained by private merchants. The models presented above provide a theoretical justification for why producer boards should, by using a buffer stock, stabilize producer prices. Interestingly, however, one would not necessarily expect a *PM* to stabilize producer prices even though part of the commodity is stored. The models also suggest that producer price instability rather than stability is consistent with an intermediary who acts as a monopolist and a monopsonist. As a result, if the possibilities are available, such an intermediary can gain by manufacturing price instability or by not stabilizing producer prices when price fluctuations are a result of natural causes.

Unlike the above results, it is in the interest of either of the market intermediaries considered to stabilize consumer prices via a buffer stock. However, prices are stabilized at a higher level when a *PM* is present. Thus consumers as well as producers are worse off when a *PM* exists rather than a *PMB*. But one should be *very*

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[8] In the comparison, an implicit but crucial assumption is that the cost structure and demand are the same regardless of the type of intermediary. This need not be true. If not, a type of comparison is needed similar to that by Comanor and Leibenstein [2] and Williamson [13] for comparing monopolies to competitive firms.

[9] Economists have for quite some time attempted to determine the shape and slope of the supply schedules for many raw products. In certain cases (e.g., Shepherd [11], Olson [9], and Khan [6]), it was found that output response was perverse. We hypothesize that in certain cases one could observe (by empirically estimating a supply schedule) a downward-sloping relationship between price and quantity supplied (e.g., *ZZ* in Figure 3) simply because one is not estimating a true supply relationship. One is merely estimating price and quantity relationships brought about by an intermediary who gains from either manufacturing price instability or from instability due to natural causes. Note also that in this case the estimated *ZZ* schedule cannot be identified as a demand schedule as it would be in Working's [14] case for competitive markets.

careful when making this type of comparison as one should be when comparing, for example, monopoly and competition. As Williamson [13] recently pointed out, from a society's standpoint monopolies can be beneficial due to the type of cost structures under different organizations. In the models here it is implicitly assumed that supply and demand for a given product are the same regardless of who does the trading. If, however, a *PM* is more aggressive than a *PMB* in promoting sales of a product, demand schedules would not be the same. It is possible that producer returns could even be higher with a *PM* trading than with a producer board. To investigate this issue is beyond the scope of this paper. However, even if this is the case, a *PM* gains by not stabilizing prices whereas a *PMB* should provide price stability if it is to maximize producer returns. Thus the welfare effects from price instability in a noncompetitive market situation critically depend on the type of actor who does the trading.

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Social Cost of Alternative Dairy Price Support Levels*

Boyd M. Buxton and Jerome W. Hammond

Government cost is important in fixing milk price supports; however, net social cost should also be a criteria. This paper develops a method of measuring the latter. The technique is applied to alternative support levels under conditions of exporting or destroying government purchases and under a condition of domestic redistribution.

Key words: Social cost; milk prices; price supports.

Decisions to change the level of milk price support under the existing dairy program should include an estimate of the associated net cost to society. This paper describes a method to provide such an estimate that is similar to the work of Johnson [2] and Wallace [8]. Net social cost obviously is not the sole criterion for policy decisions, but it should be considered along with more conventional criteria such as government program cost, farm income, milk supply and utilization, and consumer prices.

There are three basic prices determining supply and utilization of milk: the "manufacturing" milk price paid by processors of manufactured milk products; the "Class I" price paid by processors of fluid milk products (usually prices at a fixed differential above the manufacturing use price); and the weighted "all wholesale milk" price received by producers that reflects the proportion of all milk used for both fluid and manufactured products.

Although 75 percent of all milk marketed in the United States is Grade A or eligible for fluid use, only 44 percent is actually used for fluid milk products. The remaining Grade A milk is sold on the manufacturing milk market. This diverted Grade A milk along with all the manufacturing milk makes up the available supply for manufacturing purposes. It is the supply and demand of this milk for manufacturing that under the present pricing policies determines the market values of milk. The Class I price paid by processors of fluid milk products is calculated by formula from the manufacturing market price and can be approximated by using a $2.17 differential above the manufacturing price. Similarly, the all wholesale price received by producers can be approximated by using a $1.00 differential above the manufacturing price.[1]

It is the manufacturing milk price that the government must support between 75 and 90 percent of parity. Under the current price support program the government stands ready to purchase butter, non-fat dry milk, and cheese at prices sufficient to support the manufacturing milk price at the level established under the support program.

The authors' method and estimates of social costs of the price support program do not include considerations of the social benefits and costs of the discriminatory price system. That is, the federal milk marketing order program and other institutional and classified pricing arrangements and their associated social costs and benefits are assumed to be given.

Theoretical Background

The theoretical basis of this method is an aggregated community indifference curve and a community production possibility curve between milk and all other goods (numeraire). For more detailed discussion of the social cost concept, see [1, 3].

An aggregate milk supply curve can be derived from the production possibility curve. The area under this curve up to a given quantity represents the total production costs in terms of all other goods and services. A compensated demand curve can be derived from the community indifference map. Total area under this curve up

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[1] However, increasing the manufactured milk price through the support program would raise the fluid eligible price and decrease the proportion of milk used in fluid products, thereby resulting in a relatively smaller increase in the "all wholesale milk" price. The exact relationship between changes in the manufacturing milk price and the all wholesale milk price would depend, in part, on the relative elasticities of demand for fluid eligible and manufacturing milk. Because these prices maintain about a constant differential, we can make some useful simplifying assumptions about price changes; these assumptions aid in estimating the social cost of the price support program.

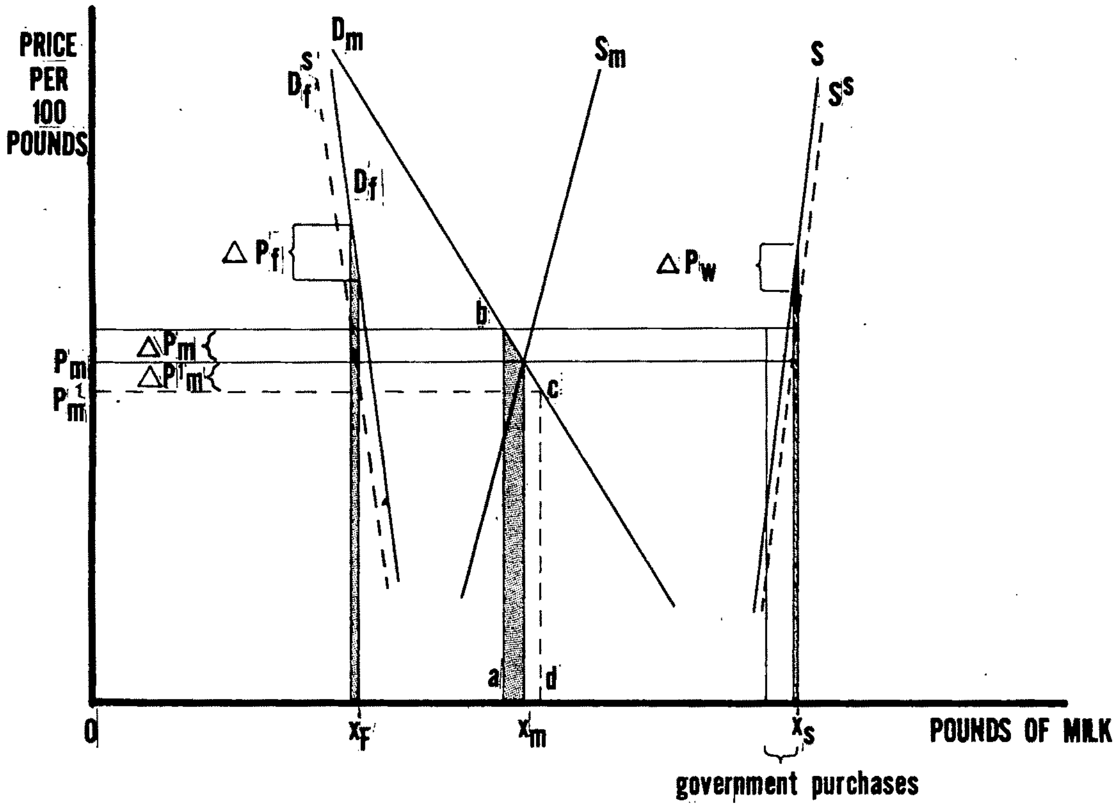

Figure 1. Impact of increasing support price for manufacturing milk on net social cost

to a given quantity is a measure of total value of fluid and manufacturing milk to the community in terms of all other goods and services.

These demand and supply curves, reflecting the two-price-level system in effect, are illustrated in Figure 1. This figure is a modified version of the more conventional two price model for milk markets. The fluid demand curve labeled D^s_f and the supply curve labeled S^s show the amount of milk demanded as fluid and the total milk supplied, respectively, at each manufacturing milk price with the assumption of a constant fluid-manufacturing price difference. The actual fluid milk price corresponding to any manufacturing price for any quantity can be determined by reading the value directly above D^s_f on the D_f curve which is the actual demand curve for fluid milk. This vertical distance between D^s_f and D_f is the differential between manufacturing milk and the Class I milk prices ($2.17).

The all wholesale milk price necessary to call forth alternative quantities from farmers and corresponding to any manufacturing price is the price directly above S^s on the S curve which is the actual supply curve for all milk. This vertical distance between the S^s and S curves is the constant differential between manufacturing milk and all wholesale milk prices ($1.00).

The area under the fluid demand curve between O and X_f and under the manufacturing demand curve between O and X_m represents the total value of fluid milk and manufacturing milk to the community in terms of all other goods.[2] The area under the supply curve and above the horizontal axis between O and X_s represents the social cost of the resources used to produce milk in terms of all other goods. Equal weights are assumed for both consumer and producers' surplus.

Maximum Social Cost

Assuming the government donates abroad or destroys its purchases, the social cost of higher support prices would be approximated by the three shaded areas in Figure 1. The shaded area under the demand curve for fluid milk and the demand for manufacturing milk would be loss of total value to the consumer, while the shaded area under the supply curve would be the cost of the added resources used to produce additional milk at the higher all wholesale milk price. This area or loss would be approximately equal to:

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[2] This assumes that both demand curves intersect the vertical price axis.

$$\begin{aligned}\text{Loss} = & (\Delta\, q^f P_f + \tfrac{1}{2}\Delta\, q^f \Delta\, P_f) \\ & + (\Delta\, q^m P_m + \tfrac{1}{2}\Delta\, q^m \Delta\, P_m) \\ & - (\Delta\, q^s P_w + \tfrac{1}{2}\Delta\, q^s \Delta\, P_w)\end{aligned}$$

where

$\Delta\, q^f$ = change in fluid consumption,
$\Delta\, q^m$ = change in manufactured milk consumption,
$\Delta\, q^s$ = change in quantity supplied,
P_f = bottling milk price,
P_m = manufacturing milk price,

and

P_w = all wholesale milk price.

This social cost can be approximated in terms of elasticity of demand for fluid and manufacturing milk, elasticity of supply, the initial prices and quantities, and the change in milk price as follows.

First, approximate the fluid demand (η_f), manufacturing demand (η_m), and supply (ϵ) elasticities with

$$\eta_f = \frac{\Delta q^f P_f}{\Delta P_f q_o^f} \qquad \eta_m = \frac{\Delta q^m P_m}{\Delta P_m q_o^m} \qquad \epsilon = \frac{\Delta q^s P_w}{\Delta P_w q_o^s}$$

where

q_o^f = equilibrium or initial quantity of milk sold for fluid use,
q_o^m = equilibrium or initial quantity of milk sold for manufacturing use,
q_o^s = equilibrium or initial quantity of milk supplied,
P_f = equilibrium or initial bottling milk price per one hundred pounds,
P_m = equilibrium or initial manufacturing milk price,

and

P_w = equilibrium or initial all wholesale price of milk, received by farmers.

Assuming constant price differentials, the following also hold:

$$P_f = P_m + a \qquad P_w = P_m + b$$

where

a = bottling milk price differential above the manufacturing price,
b = all wholesale milk price differential above the manufacturing price, and therefore,
$\Delta P_m = \Delta P_f = \Delta P_w = \Delta P$ = the increase in manufacturing support price.

The social cost can then be expressed as:

$$\begin{aligned}L \simeq\ & \eta_f\, \Delta P q_o^f \left[1 + \frac{\Delta P}{2(P_m + a)}\right] \\ & + \eta_m\, \Delta P q_o^m \left[1 + \frac{\Delta P}{2\,P_m}\right] \\ & - \epsilon\, \Delta P q_o^s \left[1 + \frac{\Delta P}{2(P_m + \text{b})}\right].\end{aligned}$$

The more elastic the supply and demand curves, the greater the social cost of a given support price increase. Also, the greater the increase in support price (or the amount the support price exceeds the free market price), the greater the social cost. In fact the social cost increases at an increasing rate for successively higher support prices above free market equilibrium prices.

Distributing Government Purchases

In reality, much of what the government purchases is distributed back to the community through various programs such as the school lunch program and other domestic donations. Assuming all the government purchases were equally distributed back to the U. S. community as manufactured products, the community would be able to achieve a higher level of satisfaction than without distribution. However, it is a lower level of satisfaction than would be attainable under market conditions. Any program distributing the government purchase of milk back to the community would reduce the dead weight social cost and allow the community to attain some higher level of satisfaction. A gift of part of the government surplus to foreign countries would be equivalent to destroying the surplus as far as the U. S. community is concerned, even though world welfare would clearly be improved.

Total social cost, represented by the three shaded areas, would be reduced by the area under the manufacturing curve labeled "a, b, c, d" in Figure 1 if all government purchases were distributed back to the U. S. community as manufactured products.

The net social cost then would be approximated as follows:

$$\begin{aligned}\text{Net loss} \simeq{} & (\Delta q^f P_f + \tfrac{1}{2}\Delta q^f \Delta P_f) \\ & - (\Delta q^s P_w + \tfrac{1}{2}\Delta q^s \Delta P_w) \\ & + (-\Delta q^f + \Delta q^s) P'_m \\ & - \tfrac{1}{2}(-\Delta q^f + \Delta q^s)\Delta P'_m\end{aligned}$$

where

P'_m = implied price necessary for consumers to purchase as manufacturing products the manufacturing milk diverted from fluid use (Δq^f) and additional milk supplied (Δq^s),

$\Delta P'_m = P'_m - P_m,$

$P'_m < P_m.$

The net social cost could then be approximated as follows:

$$\begin{aligned}\text{Net loss} \simeq{} & \eta_f \Delta P q_o^f \left[1 + \tfrac{1}{2}\left(\frac{\Delta P}{P_m + a}\right)\right] \\ & - \epsilon \Delta P q_o^s \left[1 + \tfrac{1}{2}\left(\frac{\Delta P}{P_m + b}\right)\right] \\ & - \frac{\eta_f \Delta P q_o^f}{P_m + a}\left[P'_m + \frac{\Delta P'_m}{2}\right] \\ & + \epsilon \frac{\Delta P q_o^s}{P_m + b}\left[P'_m + \frac{\Delta P'_m}{2}\right]\end{aligned}$$

where

$$\Delta P'_m = \frac{-\Delta P P_m}{\eta_m q_o^m} \left[\eta_f \frac{q_o^f}{P_m + a} - \epsilon \frac{q_o^s}{P_m + b}\right]$$

$P'_m = P_m + \Delta P'_m$

$P'_m < P_m.$

Empirical Estimates

Two kinds of related policy questions can be considered within the framework presented. First, the annual social cost of the program itself can be estimated by estimating free market prices and quantities and the amount any selected support price exceeds the free market manufacturing milk price. Second, the social cost of increasing the support levels over any current level can be estimated by using current prices and quantities and the intended increase in support price. These questions are part of the same broader problem.

Social costs estimated in this paper assume a demand elasticity for fluid milk of —0.35, for manufacturing milk of —0.5, and the elasticity of aggregate supply of 0.15.[3] These estimates are from market data. Elasticity of demand would actually represent the own demand curve for milk rather than a compensated demand curve. The own and compensated demand curves are identical when the income elasticity is zero. Since total expenditure for milk products is a relatively small part of total expenditures, it is assumed that income elasticity is small and no great distortion will result from using the empirically estimated own demand curve.

In early March 1973, the Department of Agriculture announced that the new support price for manufacturing milk would be increased from \$4.93 to \$5.29, the minimum 75 percent of parity as of April 1, 1973. The new support price became effective on March 15, 1973. To estimate the social cost of raising the support price requires estimates of the free market prices and quantity in the absence of the program. The manufacturing milk price for 1973 is expected to be about \$5.50 which would exceed the announced 75 percent of parity support price of \$5.29. Therefore, the social cost would be zero. If the support price had been raised to 85 percent of parity (about \$6.00), the support price would have exceeded the free market price by 50 cents. The estimated annual social cost for 1973 without distributing government purchases back to the community would have been an estimated \$340 million (Table 1).[4] A further increase in the support level to 90 percent of parity (\$6.35) would have increased the social cost in 1973 another \$107 million to a total of \$447 million. Annual social costs of the program itself would, therefore, be those in Table 1. The social cost of increasing the support level would be the difference between the totals in Table 1. For example, the annual social cost of the program would have been \$340 million if the support price had been set at 85 percent of parity and \$447 million if the support price had been set at 90 percent of parity. The increase in social cost of increasing the support price from 85 to 90 percent of parity is the difference between \$447 and \$340 million or \$107 million (see Table 1).

The annual social cost when increased government purchases due to the higher support price

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[3] These estimates are reported in an unpublished report to ASCS by Economic Research Service, USDA, entitled "Impacts of Alternative Price Support Levels," January 1973.

[4] 1972 production, fluid use, and manufactured were used in estimating this social cost.

Table 1. Estimated annual net social cost of alternative price support levels, 1973

	Percent of parity			
	75	80	85	90
Support price[a] (dollars)	5.29	5.64	6.00	6.35
Estimated free market price (dollars)	5.50	5.50	5.50	5.50
Amount the support price exceeds the free market price (dollars)	0	.14	.50	.65
Social cost[b]				
Without distribution back to the community (million dollars)	0	92	340	447
With distribution back to the community (million dollars)	0	13	65	94

[a] Estimated 100 percent of parity price as of April 1, 1973, was $7.05. This actually turned out to be $7.01.

[b] Excludes administrative and storage costs of the program.

are distributed back to all members of the community as manufactured products is much less at all support levels than without redistribution (see Table 1). At 85 percent of parity the estimated annual social cost would decrease from $340 to $65 million if all government purchases were distributed back to the community rather than being donated abroad or destroyed. The social cost of a combined redistribution and foreign donation policy by the government would be somewhere between the above extremes depending on the proportion redistributed and donated abroad.

Summary and Implications

A method was developed to estimate net social cost of the dairy price support program using consumer and producer surplus concepts. The method is intended to be another criterion for policy decisions regarding whether there should be a program or at what level the price support should be set. It is not intended to replace other important criteria such as government program costs, farm income levels, milk supply and utilization, and consumer prices.

Results showed that the social cost of the March 1973 decision to set the support price at the minimum 75 percent of parity was zero. Raising the support prices to 85 percent of parity would have resulted in a net social cost of $340 million if increased government purchases due to higher support price were donated abroad or destroyed. The net social cost of this same decision could be reduced to $65 million by redistributing the increased government purchases back to the United States community as manufactured products.

The method developed here has the same weakness as most tools of policy evaluation and formulation. It assumes static demand and supply curves for fluid and manufacturing grade milk. That is, elasticities are constant and there are no shifts in the curves. Shifts in one or more of these curves will lead to different social cost estimates. To the extent that shifts and changes can be forecasted, they can be incorporated into the estimating model. Generally, it is difficult to forecast these changes. Had the 1973 social cost been estimated without anticipating the shifts in demand and supply that raised manufacturing milk prices above the support level in late 1972 and early 1973, estimates would have been much higher because the free market price probably would have been underestimated.

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APPENDIX

Appendix Table 1. Selected historical price and quantity data

	Prices $1 cwt.						Billion Pounds					
	U. S.[a] Manufac. Grade P_m	Milk Used for Bottling P_f	Fluid Diff. (P_f-P_m)	All Milk[a] Whole-sale P_w	All Milk Diff. (P_w-P_m)	Support[b] Price	Milk[a] Prod.	Farm[c] Use	Milk[c] Mar-keted	Used in[d] Fluid Products	Used in[e] Manufac. Products	Gov't[a] Pur-chase
1960	3.25	5.48	2.23	4.21	.96	3.40	123.1			53.0		3.1
1961	3.36	5.43	2.07	4.22	.86	3.11	125.7			52.6		8.0
1962	3.20	5.35	2.15	4.09	.89	3.14	126.3			53.3		10.7
1963	3.21	5.31	2.10	4.10	.89	3.15	125.2			54.3		7.7
1964	3.26	5.35	2.09	4.15	.89	3.24	127.0			54.9		7.7
1965	3.34	5.39	2.05	4.23	.89	3.50	125.2	6.0	118.2	55.4	57.1	5.7
1966	3.97	5.82	1.85	4.81	.84	4.00	119.9	5.4	114.4	55.4	58.4	.6
1967	4.06	6.20	2.14	5.02	.96	4.00	118.7	5.2	113.6	54.0	52.2	7.4
1968	4.22	6.50	2.28	5.24	1.02	4.28	117.2	4.7	112.6	53.7	53.7	5.2
1969	4.45	6.70	2.45	5.49	1.04	4.28	116.1	4.3	111.8	52.8	54.5	4.5
1970	4.70	6.94	2.24	5.71	1.01	4.66	116.9	4.0	113.0	52.0	55.2	5.8
1971	4.86	7.12	2.26	5.87	1.01	4.93	118.5	3.7	114.8	51.8	55.7	7.3
1972	5.09	7.26	2.17	6.09	1.00	4.93	120.3	3.5	116.7	52.3	59.0	5.4
1973	5.50			6.50		5.29						

[a] Source [4].

[b] Source [5].

[c] Milk utilized includes milk sold to plants and dealers as whole milk and as farm separated cream and milk sold directly to consumers. Source [7, p. 4].

[d] Sales of fluid milk and cream-milk equivalent. Source [6, p. 24].

[e] Residual-milk utilized minus government purchase minus used in fluid products.

Migration Analysis and Farm Number Projection Models: A Synthesis*

JAMES A. MACMILLAN, F. L. TUNG, AND JOHN R. TULLOCH

Alternative farm number projection models are examined for the Canadian Prairie Provinces including a synthesis of Markov transition probabilities and migration functions. The procedure indicates a potential for overcoming deficiencies of standard farm projection models. Explanatory variables include: off-farm work, age of operators, capital, and regional economic structure.

Key words: **farm number projections; farm migration analysis.**

A CRITICAL analytical requirement for adequate planning for low income problems of farm operators is a model which explains changes over time in farm operator numbers by receipts class. In Manitoba the government has outlined a "stay option" with the policy intent of decreasing the past reductions in farm operator numbers. Clawson expressed the opinion in 1963 that U. S. farm policy has been excessively preoccupied with agricultural supply and demand relations, price supports, surpluses, and related problems [1]. Current criticisms of U. S. agricultural policy have made the same point in concluding that the needs of low income farm operators are not being met [20]. Policy planning and evaluation requires an improvement in methods of projecting farm target clientele by receipts class.

Past trends illustrate dramatic decreases in farm numbers since the historic peak in the late thirties. The theoretical explanation derived from economic theory and structural analysis of the agricultural industry is straightforward. Given an income inelastic domestic demand, limited export demand for agricultural products, increasing economies of size in farm production, substitution of capital for labor in agriculture, and a high growth rate and high absolute level of wages in the non-farm sectors, decreasing numbers of farm operators are required over time to meet national agricultural production requirements.

Farm number projection models have not included relationships which identify the structural significance of the factors outlined. Prior models used in projecting farm numbers can be grouped into four categories:

1. Age-demographic [1].
2. Markov chain projection assuming constant transition probabilities [4, 10, 11, 14].
3. Requirements based on assumed future average output per farm [2, 15].
4. Simultaneous analysis of the demand and supply of farm labor [30, 32, 33].

The age-demographic analysis is the simplest. Entrance and exit of farm operators are projected by age classes over a time period. Markov chain applications are based on the assumption that current values of economic variables depend on the preceding values of the same variables [18].

The requirements approach derives farm operator numbers from projected market-clearing output of agricultural products by means of the projected ratio of average output per farm. Simultaneous demand and supply analysis of farm operators provides aggregate coefficients which conceptually include components of the simple historical requirements or the demand approach as well as factors relevant to the supply of farm operators, including net income relative to urban income and urban sector unemployment.

The purpose of the present paper is to examine alternative farm number projection models for the Canadian Prairie Provinces. Included are a conventional Markov chain model and a modification of the conventional Markov chain model by an economic farm size class migration function. The traditional Markov chain model does not predict satisfactorily due to restrictive assumptions and does not provide an analysis of the relative importance of economic factors underlying the change in farm numbers. In contrast, migration functions include factors, for example, age, capital, non-farm employment opportunities, education, prices, and number of jobs held, that are generally recognized to influence future farm numbers. The procedure is

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analogous to the proposal by Hallberg [13] that nonstationary transition probabilities be estimated as a function of exogenous determinants of firm growth for manufacturing milk plants.

The age-demographic and requirements approaches are excluded due to their restrictive assumptions—changes in farm numbers are determined by a single variable age and future output, respectively. The demand and supply analysis is excluded due to the absence of relevant time-series data for the geographical areas considered to be important in the study—provinces and census divisions. Past changes in farm numbers are analyzed incorporating economic relationships to the extent possible based on available data. First, the Markov model is applied to the Prairie Provinces. Second, farm size class migration functions are estimated using Census Division observations in the Prairie Region. Third, the synthesis of migration functions and the Markov transition probabilities is illustrated by projections to 1981 for Manitoba. Offered finally are suggestions for refinements required to improve the projection procedures.

Basic Markov Process Model Applied to Farm Operator Mobility

The Markov process technique is frequently applied to project the rate of change in the size distribution of farm operators.[1] In most applications data on individual farm operator movements between states are not available. Development of improved knowledge concerning the application of Markov models in projecting the size distribution of particular industries has been reviewed by Dent and Ballintine [5]. Current Markov model applications have not included farm migration relationships.

The Markov process model using macro-data on mobility requires assumptions concerning the number entering and leaving each state in the transition matrix to be estimated for projections. Using data from the 1961 and 1966 Census, movements between size classes have been determined for Manitoba (Appendix Table 1). Gross receipts are chosen as the basis for classification due to the close correspondence between receipts and income (income is a major determinant of mobility).[2] Income size classes are designated as states of the system $S_2, S_3, \ldots, S_7$ respectively. Exit from farming is designated S_1.

Assumptions made in deriving the distribution include:

1. Increases in the number of farms in any income state, S_{i-1}, come only from the next smallest state, S_{i-1}, in the five-year period starting with S_7;
2. Any decrease in any income state means that those farms go out of farming (to state S_1); and
3. The probability of mobility between income states is constant over time.

Based on a proposal by Telser [28], Furnis and Gustafsson [11] used quadratic programming to estimate the transition probabilities matrix for dairy herd size classes using counties as micro-units. However, they found that the results were similar to the pattern of movement assumed above except that a backward movement occurred for the two largest states. The allocations in Appendix Table 1 were used to form a constant transition probabilities matrix for Manitoba.

Let S_{t-1} be a vector of farm numbers in year $t-1$; then a vector of farm numbers for subsequent years $S_t, S_{t+1}, \ldots$, etc., can be projected, based on the estimated transition probabilities matrix by:

$$P'_0 S_{t-1} = \hat{S}_t \tag{1}$$

where

P'_0 denotes the transposition of the estimated transition probabilities matrix, P_0.

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[1] See, for example, [11] for Canada, [25] for the United States, and other earlier studies in [5].

[2] Gross receipts refer to the aggregation of the value of all products sold for the 12-month period prior to June 1 of the census year.

Constant Transition Probabilities Matrix for Manitoba

$$P_0 = \begin{array}{c|ccccccc}
 & 1 & 2 & 3 & 4 & 5 & 6 & 7 \\
\hline
1 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
2 & 0.1875 & 0.6499 & 0.1626 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
3 & 0.0000 & 0.0000 & 0.4478 & 0.5522 & 0.0000 & 0.0000 & 0.0000 \\
4 & 0.0000 & 0.0000 & 0.0000 & 0.4426 & 0.4965 & 0.0609 & 0.0000 \\
5 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 1.0000 & 0.0000 \\
6 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0449 & 0.9551 \\
7 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 1.0000
\end{array}$$

Table 1. Projected number of farms by size class and number of farms leaving agriculture for 1971, 1976, and 1981 using 1961–1966 basic transition probabilities matrix[a]

Province and Region	Size Class (Based on Gross Receipts)	Number of Actual Farms in 1971[b]	Projected Number of Farms		
			1971	1976	1981
Manitoba	$25,000 and Over	2,063	3,656	8,637	14,456
	$15,000–$24,999	3,138	5,215	6,093	5,394
	$10,000–$14,999	4,263	5,287	4,671	3,661
	$5,000–$9,999	8,984	9,407	7,374	5,421
	$2,500–$4,999	6,888	5,813	3,907	2,597
	Less than $2,500	9,608	8,017	5,210	3,386
	TOTAL	34,944	37,395	35,892	34,915
	Leaving Agriculture[c]	4,725	2,313	1,503	977
Saskatchewan	$25,000 and Over	3,551	11,088	27,126	44,316
	$15,000–$24,999	7,556	16,752	17,956	13,444
	$10,000–$14,999	11,496	15,165	11,339	7,317
	$5,000–$9,999	23,840	20,236	13,060	7,805
	$2,500–$4,999	16,487	10,011	5,460	2,923
	Less than $2,500	13,773	7,933	4,068	2,086
	TOTAL	76,703	81,185	79,009	77,891
	Leaving Agriculture[c]	8,728	4,246	2,177	1,117
Alberta	$25,000 and Over	6,690	7,989	14,381	22,043
	$15,000–$24,999	7,292	9,640	11,554	11,377
	$10,000–$14,999	8,007	8,701	7,839	6,482
	$5,000–$9,999	14,246	15,283	12,579	9,905
	$2,500–$4,999	10,298	10,102	7,360	5,362
	Less than $2,500	15,991	14,768	10,754	7,823
	TOTAL	62,524	66,483	64,467	63,001
	Leaving Agriculture[c]	6,726	2,767	2,015	1,468
Prairie Region	$25,000 and Over	12,304	22,733	50,144	80,815
	$15,000–$24,999	17,986	31,607	35,603	30,215
	$10,000–$14,999	23,766	29,153	23,849	17,460
	$5,000–$9,999	47,070	44,926	33,013	23,131
	$2,500–$4,999	33,673	25,926	16,727	10,882
	Less than $2,500	39,372	30,718	20,032	13,304
	TOTAL	174,171	185,063	179,368	175,807
	Leaving Agriculture[c]	20,179	9,326	5,695	3,562

[a] Excluding institutional farms.

[b] From [26].

[c] Net reduction since the previous census.

Projection results for 1971, 1976, and 1981 for the Prairie region are shown in Table 1.[3] Projected number of farms for 1971 is 6 percent higher than the actual total number of farms. The size distribution is overestimated for the larger classes and underestimated for small classes. The projected number of farms leaving agriculture for the Prairie region is 46 percent of the actual number.

The large errors indicate the need for improvements in the method to account for migration relationships. Projection results might be improved by means of the Furnis and Gustafsson method [11]. However, the influence of exogenous factors on farm number changes would not be determined. Hallberg [13] proposed that nonstationary transition probabilities be estimated as a function of exogenous determinants of farm firm growth. A limitation of Hallberg's analysis was the difficulty of specifying appropriate milk manufacturing industry structural equations. In contrast, the structural and behavioral determinants of farm migration have been subjected to considerable analysis.

Determinants of Farm/Non-Farm Migration

Among the factors hypothesized to be important in addition to income differentials in off-farm migration are age [3, 12, 16, 23, 24, 31], assets or capital [3, 16, 31], employment opportunities outside agriculture [6, 17, 24, 30, 31], education [3, 6, 16], price [13], and number of job holdings [21]. The age variable is a proxy for future expectations and motivation. Employment opportunities outside agriculture affect the number of operators leaving farming since individuals compare the return from farming against various opportunities outside agriculture. If an operator is able to earn more in off-farm work than in farming, he could be expected to leave the farm business completely or reduce farm size in order to devote more time to off-farm work, thus increasing total returns. On the other hand, if the expected return from farming is higher than off-farm work, he will likely increase farm size. Change in operators' total days worked off the farm is hypothesized to represent employment opportunities outside agriculture and the relative return to operators between farm and non-farm work.[4]

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[3] Estimated transition probabilities matrices for Alberta and Saskatchewan are not presented in this paper. The entries in P_0 are calculated by dividing the elements in Appendix Table 1 by the 1961 row total, 3,558/18,980 = 0.1875.

It has been hypothesized that the farm operator's transition is not only determined by the relative labor return from farm and non-farm work but also by the return to the other factors owned, such as land and capital [30]. In addition, the economic structure including distance to major trade centers is different for Census Divisions within the Prairie region. Dummy variables are used to indicate such differences. Data are not available for education and number of job holdings. Adjustments are made for price changes in the next section.

Analysis and testing of hypotheses concerning the variables that explain changes in the number of farm operators by size class resulted in the following least squares regression equations for Census Division observations:[5]

$$\Delta S_i = f(\Delta X_1, \Delta X_2, \Delta X_3, \Delta X_4, D_1, D_2) \quad (2)$$

where

ΔS_i = net change in farm numbers in state i, $i = 2, \ldots, 7$, 1961–1966,
ΔX_1 = change in operator's total days worked off farm, 1961–1966, in 1,000 day units,
ΔX_2 = percent of the total number of operators less than 35 years of age in 1961.
ΔX_3 = percent of the total number of operators greater than or equal to 60 years of age in 1961,
ΔX_4 = change in total dollar value of capital stock in the agricultural industry, 1961–1966, in $1 million units,
D_1 = dummy variable equal to one for Saskatchewan and otherwise zero,

and

D_2 = dummy variable equal to one for Manitoba and zero otherwise.

The model (Table 2) performs well on the basis of R^2 and t-test criteria; the coefficients for a majority of variables are statistically significant at the 10 percent level or better. Further analysis is required to test the stability and statistical significance of the estimates for different time periods.

Negative signs of changes in total days worked off farm in the higher size classes indicate that if there were job opportunities outside of agriculture, farmers might tend to increase their time on off-farm work rather than increase farm size.[6] Thus, an increase in the job opportunities in the rural area, other things being equal, might be associated with a decrease in the number of farms in the larger size classes as well as the smallest class. An increase in the job opportunities in the rural area is positively associated with increasing the number of medium-size farms ($5,000 to $9,999). Positive coefficients are consistent with the use of off-farm income to increase farm size for the medium-size classes.

The sign of coefficients for the number of operators less than 35 years and greater than 60 years of age varies among the size classes. It was hypothesized that Census Divisions with a larger proportion of operators under 35 years of age would have a net positive effect on the number of farmers in all receipts classes. The signs are not consistent with the hypothesis

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[4] This is based both on the results of Kaldor and Jetton [16, p. 747] that farm entrants acquire necessary knowledge through formal schooling and acquire necessary capital through non-farm employment and also on the finding from a random sample of 59 from a total of 617 Manitoba farm operators who received training in the winter of 1971–72 that 16 percent could not achieve farm size goals without off-farm work [19, p. 35]. This is interpreted as the use of non-farm income for farm investment.

[5] Land and buildings, and machinery and equipment initially specified in the model are highly correlated (.9) and were replaced with total value of capital stock. Aggregate values of variables provided better results than per farm average variables. Age initially specified as the change in the number by age class was respecified to remove bias as suggested by an anonymous reviewer.

[6] An alternative interpretation is that the more time spent in off-farm work, the less time is spent on the farm operation and consequently the lower the likelihood of increasing farm size. Additional analysis is required.

Table 2. Estimated regression coefficients of equation (2)[a]

Receipt Class		Constant a_i	Δ Off-Farm Work ΔX_1	Percent of Operators <35 ΔX_2	Percent of Operators >60 ΔX_3	Δ Capital Stock ΔX_4	Saskatchewan D_1	Manitoba D_2	R^2
$25,000 and Over	S_7	82.525	—.00115**	—3.876+	.190	—.00000155**	—52.172**	—22.437+	.878
		(76.185)	(.000243)	(2.325)	(2.038)	(.000000106)	(11.074)	(13.649)	
$15,000–$24,999	S_6	—280.917*	—.00150**	6.305	5.039	.00000286**	103.845**	83.200**	.883
		(159.177)	(.000509)	(4.857)	(4.257)	(.000000222)	(23.137)	(28.518)	
$10,000–$14,999	S_5	—35.178	.000473	3.689	—6.439	.00000269**	197.515**	139.090**	.731
		(290.580)	(.000929)	(8.867)	(7.772)	(.000000405)	(42.237)	(52.060)	
$5,000–$9,999	S_4	1488.620**	.00773**	—34.225*	—45.318**	—.000000970	207.285*	36.429	.445
		(602.038)	(.00192)	(18.371)	(16.101)	(.000000838)	(87.507)	(107.860)	
$2,500–$4,999	S_3	295.162	.00135	—12.011	4.514	—.00000525**	—257.573**	—209.435**	.816
		(399.443)	(.00128)	(12.189)	(10.683)	(.000000556)	(58.060)	(71.563)	
Less than $2,500	S_2	—1964.340*	—.00694**	51.379*	50.918*	—.00000308**	—400.717**	—85.023	.556
		(808.616)	(.00258)	(24.674)	(21.626)	(.00000113)	(117.534)	(144.870)	

[a] The values in the parentheses are standard errors.
+ Statistically significant at the 10 percent level (1.299) for a one-tailed *t*-test.
* Statistically significant at the 5 percent level (1.676) for a one-tailed *t*-test.
** Statistically significant at the 1 percent level (2.405) for a one-tailed *t*-test.

with the exception of farm operators with receipts less than $2,500. It was expected that an increase in the proportion over 60 years of age would have a negative effect on the number of operators across all classes. The positive coefficient for the less than $2,500 class is inconsistent with the expectation, but the results support the hypothesis for the $5,000–$9,999 and the $10,000–$14,999 class. Results indicate net effects of aging are more complex than assumed in the age-demographic analyses.

Negative capital coefficients for the two smallest size classes indicate that an increase in capital stock is associated with a decrease in the number of farms in the small size classes, implying that there will be a movement from a smaller farm size to a larger farm size or exit with additional capital investments in an area. Positive coefficients for the classes over $9,999 indicate the magnitude of the relationship between increasing capital investments and increasing farm numbers in the higher receipts classes. The significant dummy variables for Saskatchewan and Manitoba indicate that unique Provincial characteristics within the Prairie region affect changes in farm numbers in addition to the variables included in the equation.

Adjustment of Projections for Migration Determinants and Price Changes

Projections to 1981 for Manitoba are made to illustrate the adjustments required to synthesize migration concepts and price changes in the Markov model. Projections are made in successive steps. First, the transition probabilities are adjusted by means of the estimated migration relationships (Table 2).[7] Actual 1966 totals are replaced with estimates, $\hat{S}_{it}$, calculated by adding the increment in farm operators derived from the migration functions, $\Delta\hat{S}_i$, to the 1961 farm operator numbers by class:

$$(3) \qquad \hat{S}_{it} = S_{io} + \Delta\hat{S}_i.$$

Allocations are then made according to the assumptions outlined above for Appendix Table 1. The resulting transition matrix provides estimates of the change in operators associated with changes in the independent variables in the migration equation.

Second, an adjustment is made for the effect of the 10.9 percent increase in the index of prices received for farm commodities for 1961–1966 in Manitoba [27]. It is assumed that farm operator numbers are uniformly distributed in each class. For example, 10.9 percent of the farm operators who moved from the $15,000–$24,999 class to the over $25,000 class are estimated to have moved due to the price increase.[8]

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[7] Projections were also made on the basis of equations re-estimated to include only variables significant at the 10 percent or more level by the procedure of "backward elimination" [9, pp. 167–168]. The coefficients of variables in the projection equations are close to the values in the initial model except for capital in the $25,000 and over class which became negative. The resulting sign change is consistent with the prior hypothesis. One nonsignificant variable, age under 35 for the $2,500 to $4,999 class, became significant. However, projection results based on the re-estimated equations do not differ substantially.

[8] For the years 1961, 1966, and 1971, the Statistics Canada farm commodity price indexes for Manitoba were 100.0, 110.9, and 100.5 respectively. The 1961–1966 values for independent variables for Manitoba are given in Appendix Table 2.

Table 3. Actual and projected farm number by gross receipts class in Manitoba, 1961–1981

	Actual[a]						Projected					
	1961		1966		1971		1971		1976		1981	
Gross Receipts Class	Farm Number	Percent of Total	Farm Number	Percent of Total	Farm Number	Percent of Total	Farm Number	Percent of Total	Farm Number	Percent of Total	Farm Number	Percent of Total
Less than $2,500	18,980	43.77	12,336	31.07	9,608	27.50	7,331	20.09	4,357	12.60	2,589	7.74
$2,500–$4,999	12,095	28.01	8,502	21.41	6,888	19.71	6,110	16.74	4,167	12.05	2,749	8.22
$5,000–$9,999	8,966	20.76	10,647	26.81	8,984	25.71	9,478	25.97	7,720	22,32	5,889	17.60
$10,000–$14,999	1,971	4.56	4,452	11.21	4,263	12.20	5,264	14.42	4,828	13.96	3,992	11.93
$15,000–$24,999	868	2.00	2,556	6.44	3,138	8.98	4,920	13.48	5,930	17.14	5,594	16.72
$25,000 and Over	386	0.90	1,215	3.06	2,063	5.90	3,393	9.30	7,587	21.93	12,642	37.79
TOTAL	43,266	100.00	39,708	100.00	34,944	100.00	36,496	100.00	34,589	100.00	33,455	100.00
Leaving Agriculture			3,558		4,725		3,211		1,908		1,134	

[a] From [26]. The effects of under-enumeration of small farms noted in the introduction to the Census publication require analysis.

Finally, projections of the farm operators distribution for 1971 (Table 3) are derived by multiplying the transposed transition probability matrix by the vector of actual farm operators by class in 1966 [see eq. (1)]. Projected farm number distributions for 1976 and 1981 in Table 3 are based on the assumption that the estimated transition probabilities matrix for 1961–1966 is constant over the period to 1981. The procedures outlined could be refined by projecting farm number distributions for 1976 and 1981 based on alternative assumptions concerning the independent variables in the migration function and migration estimates based on 1966–1971 Census data.

Conclusions

There is a potential for overcoming deficiencies of standard methods of projecting farm operator numbers by receipts class by using migration functions to revise Markov transition probabilities. The method provides considerable information concerning the likely impacts on the distribution of farm operators by receipts class of price changes and changes in values of the determinants of migration (including off-farm work, age of operators, capital, and regional economic structure). The Manitoba projections for 1971 based on the adjusted matrix have a substantially lower percentage error in five out of seven classes relative to the initial Markov projections (Table 1), and the total is high by 4 percent compared to the previous high estimate of 7 percent. Model projections would likely be substantially improved by analysis of the micro-data scheduled to be available from the record linkage of the 1966 and 1971 agriculture and population Censuses in Canada. The record linkage will permit microanalysis of the gross migration flows of present farm operators and characteristics of entering farmers, an improvement over the present analysis based on net movements [29].

Perkins [22] concluded from an age cohort analysis of Census data and monthly Labor Force Survey data that an ideal source for predicting changes in agricultural employment would combine the time-series advantages of the Labor Force Survey with the structural data provided by the decennial Census, particularly a distribution by farm size. The present study derives cross-section estimates based on Census Division observations for 1961–1966 changes in structure by farm size. The analysis could be updated and adjustments made for changes in coefficients when complete information becomes available from the 1971 Census. In addition, Labor Force Survey data could be utilized to provide annual estimates, and the analysis could be expanded to include the hired labor and unpaid family labor components to provide a more complete picture of the farm labor market in Canada on a regional and subregional basis.

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APPENDIX

Appendix Table 1. Allocation of farms between classes in Manitoba, 1961–1966[a]

To \ From		S_1 Exit	S_2 Less than $2,500	S_3 $2,500–$4,999	S_4 $5,000–$9,999	S_5 $10,000–$14,999	S_6 $15,000–$24,999	S_7 $25,000 and Over	Total 1961
Exit	S_1	0	0	0	0	0	0	0	0
Less than $2,500	S_2	3,558	12,336	3,086	0	0	0	0	18,980
$2,500–$4,999	S_3	0	0	5,416	6,679	0	0	0	12,095
$5,000–$9,999	S_4	0	0	0	3,968	4,452	546	0	8,966
$10,000–$14,999	S_5	0	0	0	0	0	1,971	0	1,971
$15,000–$24,999	S_6	0	0	0	0	0	39	829	868
$25,000 and Over	S_7	0	0	0	0	0	0	386	386
Total (1966)		3,558	12,336	8,502	10,647	4,452	2,556	1,215	43,266

[a] Excluding institutional farms. Starting with the $25,000 and over gross receipts class, there were 1,215 farms in 1966, an increase of 829 over the number in 1961. It is assumed that the entire 829 came from the next smallest class. In 1961 there were 868 farms in the $15,000–$24,999 class; with 829 moving up, 39 are left. In 1966 there were 2,556 farms in the $15,000–$24,999 class; with 39 remaining, the remainder must come from the next smallest classes—all of the farms in the $10,000–$14,999 class, 1,971 in 1961 and the remaining 546 from the $5,000–$9,999 class. The same procedure is used to determine the remainder of the elements. The distributions for 1961 and 1966 are taken from [26].

Appendix Table 2. The values and the rates of changes in total days of off-farm work, number of operators, and capital stock for Manitoba, 1961–1966

	1961	1966	Change
Total Days Off-Farm Work[a] (1,000 Days)	1,422.1	1,503.4	+81.3
Mean Census Division Percentage of Operators Less than 35 Years Old[b]	11.6		
Mean Census Division Percentage of Operators 60 Years and Over[b]	19.3		
Capital Stock[c] (Million Dollars)	1,154.1	1,757.4	+603.3

Sources: [7, 8].

[a] Defined as work performed for wages, salaries, and commissions, as well as income from custom work, non-agricultural business, or professional practice.

[b] The mean (1961) Census Division age variables were multiplied by 20, the number of Manitoba Census Divisions, to obtain the value of the independent variables in estimating ΔS_{it} in equation (3).

[c] Estimated market (regardless of tenure) value of land and buildings, machinery and equipment (including automobiles), and livestock and poultry.

The Impact of Benefit Spillovers upon Economic Efficiency in Public School Finance*

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The hypothesis that public school funding is sensitive to gain or loss of residence related external benefits was tested using two stage least squares. No statistically significant relationship was detected. Arguments for providing school funding relief to declining rural areas must be defended upon equity rather than efficiency grounds.

Key words: **outmigration; economic efficiency; school finance.**

PRIMARILY because of labor-saving technological change in agriculture, many rural communities have witnessed extremely high rates of post-high school outmigration.[1] As a consequence, a relatively large proportion of the population in these communities is elderly, and much of the taxable property is owned by the elderly. The combination of long-run outmigration and increasing taxable property ownership by those who no longer have children in school has led to concern about the provision of adequate public education in rural areas. The purpose of this paper is to report upon an investigation into the relationship between migration and school funding. Interest is specifically focused on the hypothesis that migration, because it creates positive spillovers of a public good valued by communities, results in a suboptimal investment in public education.[2]

Educational Benefits and Spillovers

First, it is appropriate to review in some detail the nature of education and the possible importance of benefit spillovers.[3] From the individual viewpoint the value of education derives principally from two components: the utility of education as a consumption good and the additional earnings resulting from additional education. Of lesser importance are what Weisbrod [9, p. 23] has identified as the option to pursue still further education and the hedging option: the increased ability to adjust to technological change.

Schooling benefits which accrue to society have been less well investigated and take both monetary and nonmonetary forms. Nonmonetary external benefits from education arise mainly from the greater sense of social conscience usually associated with education.[4] A more direct but often overlooked product of the schooling process is the service of child care. Schools make it possible for mothers who would otherwise be caring for their children to engage in other activity. A related but difficult to measure effect is the school's impact on levels of juvenile delinquency. Time spent in school is time not spent in unsupervised play, the consequences of which may be increased antisocial behavior.

Residence related external benefits are those which are enjoyed by society but which are tied to the individual. The community in which the individual resides is thus the primary beneficiary. An obvious but not entirely residence related external benefit from education is the increased tax revenue which derives from educationally induced increased income.[5] Also of importance are

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[1] In a study of migration patterns of Eastern Oklahoma high school graduates, Holland [4, p. 163] found that approximately 96 percent of the human capital developed in small Eastern Oklahoma communities migrated out of the community. For larger communities in the same area, the outmigration of locally developed educational capital was on the order of 84 percent.

[2] Empirical testing of the hypothesis under examination is believed especially critical in view of the implications for school funding, particularly for rural areas experiencing high rates of outmigration. Should there be evidence of the hypothesized relationship between school funding and benefit spillovers, adjustment in the present system of public school finance could be justified for efficiency as well as the more obvious and previously investigated equity reasons (cf. [3 and 4]).

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[3] For an excellent and very comprehensive discussion of the direct and indirect benefits of education, see Weisbrod [9, pp. 15–100].

[4] The external benefits being referred to in this and in future contexts are those external to the individual.

[5] The increased income under discussion is presumed

the secondary effects upon community income and employment levels.[6]

An additional real benefit from education is the cost of not providing an adequate education. Inferior education is conducive to high crime and unemployment. The lower incidence of these factors among the better educated must be counted as a true benefit of education.[7] Knowledge that the problems of crime and unemployment are exported through outmigration may provide an important rationale for underinvestment in education at the local level.

The point is that tax effects, secondary income effects, and what have been called real cost effects are tangible. They may be of sufficient importance to attract explicit community attention. The purpose of this paper is to determine if the spatial shifting of these effects through migration of the educated seems to influence school funding behavior.

Previous Work and the Conceptual Model

Weisbrod [9, p. 6] hypothesized that voters in a school district explicitly consider potential benefit spillouts in determining the level of education expenditures. He assumed that spillins would be regarded as independent of expenditures and, thus, not a factor in the expenditure decision. Under these conditions, if voters were to behave as welfare maximizers, referendum procedures would result in education being funded at a less than optimal level.[8]

The idea that a spillover of benefits would cause separate local governments—presumed to be acting independently—to provide a quantity of a local public good that was less than pareto optimal generated considerable theoretical debate (cf. [2, 5, 7, 9, and 10]). The debate took the form that under the assumption that communities act independently it was inappropriate to argue that benefit spillovers would necessarily cause local governments to provide a suboptimal quantity of a local public good.[9] It will be shown that to the degree it is appropriate to view education as a public good, it will be provided in a suboptimal fashion in the presence of benefit spillovers.[10]

In the present analysis, schooling was assumed to be publicly provided through tax revenues. Communities were assumed to attempt to maximize net benefits in the sense of quality of education provided and taxes charged. All external benefits were assumed to be residence related. The marginal cost of producing additional units of educational output (quality) was assumed constant and equal for all communities. Education was assumed to be a normal good.

Voters living in the school district or community—the terms are used synonymously—were visualized as falling into two groups. One group would consist of families who have children in school or expect to have them in school. The quality of education demanded by families in this group would be largely a function of the previously mentioned direct benefits. To them, the external benefits deriving from the education of others' children would be secondary. Group two would consist of families who do not have and do not expect to have children in school. Their demand for education would derive only from external benefits. Consequently, this group's demand would be directly dependent upon the proportion of residence related benefits expected to remain in the community.

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to result from increased educational quality rather than increased levels of education.

[6] Secondary income and employment effects may be particularly important in declining rural areas if outmigration of the educated results in decline in population below the threshold required to support certain key enterprises.

[7] Demand for many public services is probably sensitive to education. The net effect upon public service budgets remains unclear. For example, well-educated people may require less crime prevention and detection, but demand more library and symphony services.

[8] The assumption that decisions about public education are made with expected benefits in mind raises some interesting and largely little researched questions. It is not at all certain that voters view education within the benefit maximizing model. Even if that assumption is accurate, education expenditures are a function of decisions by an elected School Board and special elections on tax levies and debt financing. Board members may or may not reflect their constituents' desires or act if they were a maximizing firm. A related but also little investigated area is the relationship between voting patterns and alternative tax structures. The most important tax for nearly all school districts is the property tax. The pattern of tax burden imposed by this tax in relation to expected benefits is not likely to lead to a majority decision on education expenditures that is optimal. Barlow [1], using data from the state of Michigan as an illustration, estimated that the residential property tax resulted in a level of educational output 26 percent below the optimum.

[9] The crux of the argument centered around Williams' [10] apparent demonstration that the Pareto optimal equilibrium could involve either a greater or lesser amount of the public good than would be produced under independent community adjustment. Brainard and Dolbear [2] then showed that Williams' Pareto optimal equilibrium resulted in an income redistribution between communities and was thus invalid.

[10] The conceptual model developed in this paper draws heavily upon Pauly's [7] earlier work.

Assuming that the rationality postulate of consumer behavior applies to public education, the optimal amount of education for the children in the *i*th family in the *J*th community would equate marginal costs with marginal benefits at the community level. That is, under the assumption of no migration between communities, the optimal amount of education, X_{iE}, for children in family i in community J satisfies the following condition:

$$\frac{u_{iE}}{u_{ir}} + \sum_{j \text{ in } J} \frac{u_{jE}}{u_{jr}} = \frac{f_E}{f_r}$$

where u_{iE} is the marginal utility of education to the *i*th family; u_{ir} the marginal utility of a private numeraire good with cost equal to one dollar; u_{jE} is the marginal utility of *i's* education to family j; f_E/f_r, the ratio of marginal costs.

If migration occurs and the potential migrants cannot be identified before the event, the net benefit maximizing community would select that amount of education which satisfies the following equation:

$$\frac{u_{iE}}{u_{ir}} + \sum_{j \text{ in } J} (1-P_J)\frac{u_{jE}}{u_{jr}} = \frac{f_E}{f_r},$$

where P_J is the probability that the students will leave community J. The second term of the equation clearly indicates that the immediate effect of outmigration is to reduce community willingness to support education in direct proportion to loss of external benefits associated with education.[11]

The independent-provision equilibrium can be seen to be suboptimal. The optimal amount of education is defined by

$$\frac{u_{iE}}{u_{ir}} + \sum_{j \text{ in } J} (1-P_J)\frac{u_{jE}}{u_{jr}} + \sum_{A \text{ in } Z}\ \sum_{k \text{ in } A} P_A \frac{u_{kE}}{u_{kr}} = \frac{f_E}{f_r},$$

where P_A is the probability of migration into community A in the set of communities, Z, and u_{kE} represents the marginal utility of education *i's* children to family k in community A. That is, the potential benefit of education for children in family i in community J accrues to the family, to the other citizens of community J, and to all other citizens in communities to which migration may occur. To the degree that the latter element is important, independent community provision of education will be suboptimal.[12]

Data, Tests, and Findings

The spillover-suboptimal funding hypothesis was tested by Weisbrod [9, pp. 107–116] by regressing expenditures for public education on state net migration rates—net in and out-migration were entered as segmented variables. The regression analysis indicated a negative relationship between outmigration and educational expenditures per student and no relationship between immigration and educational spending.

The test, however, was weakened somewhat by a partial lack of correspondence between the conceptual model and the data. The two most serious problems were the inclusion of federal expenditures in the dependent variable and the choice of net migration to represent spillovers. Quite clearly, the dependent variable should represent only that portion of schooling expenditures under control of the governmental unit being examined.[13] The difficulty with the spillover indicator was that gross rather than net migration may be the more appropriate measure, and rates of gross migration cannot be accurately represented by net migration data. It is not unreasonable to assume that an area would regard outmigration of the locally educated as a loss only if they are not replaced through inmigration. However, it is possible that gross migration is the more appropriate measure. Accordingly, both net and gross migration rates were examined as spillover indicators in the present study.

In order to construct a test of the implications of the conceptual model, several important assumptions were made. The relationship between individual demand for education and demand at the community level has not been well researched. Decisions on schooling output are a function of the referendums on both school board membership and direct school bond levies. Here it was implicitly assumed that the school boards accurately reflect the demand of their constituents who, as stated before, were assumed to behave as if they were net benefit maximizers. The important factors influencing the demand for education were hypothesized to be price (cost) per student, community wealth, and spillovers.

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[11] Not directly reflected in the equation but worth noting are the effects of prolonged net outmigration. In communities experiencing population decline through outmigration of the young, external benefits as opposed to direct benefits should become increasingly important in determining community expenditures.

[12] With the aid of a modified Edgeworth box [7, p. 575] it can be proven graphically that once all communities have arrived at the independent adjustment optimal output, X_E, there is no mutually beneficial Pareto-optimal point at which output will be less than X_E. This assumes community recognition of both spillins and spillouts.

[13] The existence of inter-governmental grants makes determination of the effect of benefit spillovers on expenditures especially difficult. Even if the extra-local contribution to expenditures is not included, its effect on local budgets still remains. This is part of the rationale for taking the simultaneous equations approach presented later.

The supply curve for education was assumed to be upward sloping and identical for all communities.[14] Should these assumptions be satisfied, local decisions about educational output would be accurately reflected in local expenditures per student and determination of impact of migration would be relatively simple. The presence of state foundation aid, however, complicates matters.

The typical "foundation plan" establishes a dollar level of spending which it guarantees to every district. To qualify the district must tax its property at a specified minimum rate. The amount of revenue raised by the district at that tax rate will be supplemented by the state to the degree necessary to achieve the foundation level. The difficulty is that foundation aid tends to be high in areas where property values are low, and such areas are also characterized by high rates of outmigration. Thus, unless care is taken, migration rates will represent the effect of foundation aid rather than benefit spillovers. For this reason the local funding decision was assumed, in addition to the previously hypothesized factors, to be a function of the level of state foundation aid. Both the community demand for education and the level of state aid were viewed as functions of community wealth. Since local and foundation aid revenues were treated as jointly determined, a simultaneous equation approach was employed.[15]

The structural model is summarized by the following functional relationships:[16]

Local Revenues

$$L = f(P, F, SI, SO, u_1) \tag{1}$$

State Foundation Revenues

$$F = g(P, Y, u_2) \tag{2}$$

State Ear-marked Revenues[17]

$$E = h(P, Y, u_3) \tag{3}$$

where the endogenous variables are

L = Local revenues per student in average daily attendance/ADA;
F = Revenues from the state foundation aid program/ADA;
E = State revenues ear-marked for elementary and secondary education/ADA;

the exogenous variables are

P = Assessed value of property/ADA;
Y = Income/ADA;
SI = Spillins, measured as either the gross or net inmigration rate/ADA;
SO = Spillouts, measured as either the gross or net outmigration rate/ADA;

and

u_i = Disturbance term with mean zero and diagonal covariance matrix having constant variance and $E(u_i u_j) \neq 0$ for $i \neq j$.

Data representing migration, public school revenue, and assessed valuation were collected from Oklahoma State Economic Areas [6, 11]—SEA's. Choice of the unit of inquiry was conditioned by the existence of the necessary migration data. The smallest geographical unit for which gross migration data were available was the state economic area. School district data would have been preferable, but the necessary migration data were not available by school district. Valid use of SEA data as opposed to district data requires the assumption that SEA migration patterns are representative of movements occurring within the individual districts and that the population of migrants contains a sufficiently large percentage of recent high school graduates to be representative of post-high school migration rates. It is also necessary that districts be relatively homogeneous within SEA's with regard to financing.

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[14] Usual data sources do not permit observation of the relationship between price and units of educational quality. Instead, the product of these variables is observed in the form of expenditures per student. In order for expenditure variation to represent variation in demand accurately, it was necessary to restrict supply. Although there may be a relationship between population density and supply, the data in this study were not thought to exhibit sufficient density variation to invalidate the supply assumption.

[15] Although determination of actual levels of local and state spending for education is surrounded by many institutional constraints, it is quite reasonable to expect that one of the most important factors entering into determination of local support is the expected level of state support.

[16] The reason for specifying the structural equations in revenue rather than expenditure units was that expenditure data were not identified by government funding unit. Since accurate testing of the spillover hypothesis required that the impact of foundation program be accounted for, it was necessary to approach the problem from the revenue side rather than from the expenditure side.

[17] Although ear-marked revenues were not viewed as affecting either state aid or local support, they are an important revenue source in Oklahoma and there was interest in determining the degree that they were related to income and/or property.

In Model I, spillins and spillouts were represented by rates of gross in and outmigration.[18] Estimates of the coefficients were obtained by the method of two-stage least squares (TSLS). Standard errors are shown beneath the coefficients.[19]

Model I

$$(1)\quad \begin{aligned} L = {} & \underset{(51.443)}{169.410} + \underset{(2.435)}{7.784P} - \underset{(0.301)}{0.757F} \\ & + \underset{(1.052)}{0.274SO} - \underset{(1.029)}{0.298SI} \end{aligned}$$

$$(2)\quad F = \underset{(20.636)}{319.130} - \underset{(0.958)}{4.059P} - \underset{(1.581)}{11.699Y}$$

$$(3)\quad E = \underset{(11.565)}{26.327} + \underset{(0.536)}{2.016P} + \underset{(0.886)}{0.957Y}$$

Both property value and foundation aid had a significant and expected effect upon local funding. Once the effect of property and foundation aid variation was accounted for, however, neither in nor outmigration had a significant impact upon local education funding.[20] The second equation indicates that foundation aid was strongly and negatively related to property and income. Ear-marked revenues were related only to property.

The possibility that spillovers—assumed to be perceived by the community in the form of net migration—were an important factor was examined by replacing the gross migration variables with net migration.[21] In Model II, the variables representing spillovers were defined by net in and outmigration rates entered as segmented variables.

Model II

$$(4)\quad \begin{aligned} L = {} & \underset{(52.022)}{164.050} + \underset{(2.406)}{7.860P} - \underset{(0.318)}{0.693F} \\ & + \underset{(1.375)}{0.487SO} - \underset{(1.713)}{1.932SI} \end{aligned}$$

$$(5)\quad F = \underset{(20.636)}{319.130} - \underset{(0.957)}{4.006P} - \underset{(1.581)}{11.649Y}$$

$$(6)\quad E = \underset{(11.565)}{26.327} + \underset{(0.536)}{2.016P} + \underset{(0.886)}{0.958Y}$$

In Model II as in Model I there was no evidence of any relationship between spillovers and school funding at the local level.[22] The other coefficients in Model II remained essentially the same as in Model I.

Conclusions

The findings of this study do not support the hypothesis that spillouts or spillins of residence related external benefits associated with education exert a consistent and measurable influence on local willingness to finance education. There are several plausible reasons for the apparent lack of spillover impact. The external benefits of education are probably not viewed as very important. Thus, the gain or loss of these benefits through migration generates very little direct pressure for funding adjustment. The presence of state foundation aid also lessens the strength of possible spillover impact. The correlation between foundation aid and net outmigration was high and significant at .73. This means that the state foundation aid program has to some degree internalized benefit spillovers, thus diminishing the likely effect of spillovers on local school funding. Finally, decisions about the size of school budgets may well have become so institutionalized that response to spillovers or anything else for that matter may be virtually impossible.

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[18] Observations on migration were expressed in percentages of the 1960 student population.

[19] The concentration parameter associated with equation (1) was $\mu^2 = 49.50$—a relatively large value. This means that in the exactly identified case of equation (1) the distribution of (TSLS) estimates will be approximately normal [8]. In equations (2) and (3) the F values indicating the statistical significance of coefficients restricted to zero by model specification were not significantly different from zero at the .05 level.

[20] The simple correlations provided no evidence of a migration influence on school funding. The correlation with local revenues was 0.05 for outmigration and 0.07 for inmigration.

[21] Although it is not apparent from the estimated coefficients, the complete lack of correlation between gross and net migration data should be noted. The correlation coefficients between net migration and gross in and outmigration were 0.22 and 0.02, respectively. The point is that should a hypothesis call strictly for gross migration rates—not the case here—use of the often more easily available net migration rates is to be avoided.

[22] The spillover-school funding phenomenon was also examined on a county basis. A single equation approach was used with net migration as the spillover proxy and a larger set of explanatory variables, such as non-white enrollment, percentage of population in school, population density, and location. Although the relationships which emerged between local funding and the independent variables were interesting, the conclusion on migration remained the same—no significant effect [4, p. 62].

In all fairness it should be pointed out that the analysis is replete with untested assumptions. Both the conceptual and empirical sections are somewhat awkward in isolating the critical aspects of the problem. For example, the assumptions required for local revenues per student to reflect accurately actual community decisions on educational output may not be satisfied. The data, because of the desire to examine gross as well as net migration, are fairly highly aggregated and may average out variation in local decisions. Also, citizens may view the provision of education as a duty and be little concerned with future benefits—eliminating the appropriateness of the benefit maximizing model.

Others wishing to pursue the spillover-suboptimal school funding theme will have to find better data, more incisive methods of analysis, and improved knowledge of the values of local decision makers. Until such studies appear, the conclusion suggested by the weight of the evidence in this paper is that economic efficiency as it relates to school spending and benefit spillovers is not endangered under the present system of school finance. Arguments using benefit spillouts as the rationale for providing some form of school funding relief to declining rural areas will have to be defended upon equity grounds.

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Changes in Industries Located in the Nonmetropolitan South, 1959–1969*

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Southern counties more than 50 miles from an SMSA experienced nonfarm job growth in the 1960's. Manufacturing jobs, especially in electrical equipment, transportation equipment, chemicals, and furniture industries shifted more toward nonmetro locations. Consequently, the Southern nonmetro industry mix was not solely of the lowest-wage and most labor-intensive components.

Key words: **nonmetro industrialization; industry-mix; industrial locational patterns.**

THE growth of nonfarm jobs in Southern[1] nonmetropolitan areas was quite large in the 1960's.[2] For example, manufacturing employment in Southern nonmetro counties over 50 miles from a Standard Metropolitan Statistical Area (SMSA) grew by 61.1 percent (a net gain of 308,972 jobs) from 1959 to 1969, while Southern SMSA manufacturing increased by 43.7 percent (a net gain of 701,916 jobs).[3] This paper will cover two related questions: Which are the most nonmetropolitan industries in the South in their locational patterns? And to what extent did these patterns change in the last decade?

Nonmetropolitan is defined here as the concept of spatially nonmetropolitan labor markets. Operationally, it includes all Southern counties more than 50 miles from an SMSA, in order roughly to exclude "SMSA fringe" areas. In contrast, metro labor markets will refer to all SMSA counties (as designated in 1969) plus all nonmetro counties 0–50 miles from an SMSA. Data are from a one-third random sample of southern counties, stratified by distance from the nearest SMSA [4, 5].[4]

In order to analyze the main questions of this note, the nonmetro industrial share was computed. This share is defined as the percentage of a given industry's total Southern employment which was located in nonmetro labor markets as opposed to the "rest of state" areas in the South. Thus, a nonmetro share of 36 percent for the apparel industry means that 36 percent of its southern jobs were located in counties more than 50 miles from an SMSA.

Results

The results for the broad, "one-digit" industries are presented in Table 1. Mining, agricultural services, and manufacturing have the highest nonmetro shares in 1969; finance, insurance, and real estate, construction, wholesale trade, and services possess the lowest.

Since this picture is hardly surprising, more interesting results are those within the important export base sector of manufacturing (Table 2). The nonmetro share by SIC product ranges from 0.0 to 44.3 percent. This range indicates considerable variation between the industrial composition of southern nonmetro and SMSA areas in 1969. However, it seems more interesting to ask which industries are *changing* their propensity to locate in nonmetro areas (i.e., which are shifting from nonmetro to "SMSA" labor markets or *vice versa*). Tables 1 and 2 reveal the following trends.

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[1] In this article the South is defined as the 13 state area made up of the states of the Confederacy plus Oklahoma and Kentucky less Texas, Georgia, and Kentucky which had to be dropped because of data deficiencies.

[2] The size of such increases was shown by Haren [1] and by the author [2, Chapter 2]. A summary of [2] is available from the Center for the Study of Human Resources, University of Texas at Austin.

[3] See [2, Table 2-1, pp. 39–40]. The Table is based on *County Business Patterns* data and the listing of SMSA counties is that of 1969.

[4] Because of the significance of the larger nonmetro counties (i.e., those whose main city's population was over 10,000), their sampling proportion was later raised to 100 percent. Thus the final list of sample counties included 147 counties of the total 326 Southern nonmetro labor market counties (47 percent), and 65 percent of their total nonfarm employment. (Sample totals from the *smaller* nonmetro counties were expanded by appropriate employment multipliers in order to compensate for their lesser sampling fraction).

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Table 1. Ten-state South: nonmetropolitan share[a] of manufacturing industries, 1959–1969, by major industry groups[b] arrayed by share in 1969

Industry	1959 Nonmetro Share of Industry Jobs		1969 Nonmetro Share of Industry Jobs		Change, 1959–1969 Nonmetro Share of Industry Change	
	Percent	Number	Percent	Number	Percent	Number
Total Nonfarm Employment	16.6	973,568	16.8	1,481,988	17.3	508,420
Mining	38.7	35,590	28.5	36,742	3.1	1,152
Agricultural Services, Forestry, and Fishing	22.3	5,349	23.2	10,171	24.3	4,822
Manufacturing	18.3	383,879	20.0	623,101	23.4	239,222
Retail Trade	17.3	210,810	17.4	298,506	17.4	87,696
Transportation, Communication, and Public Utilities	13.6	53,731	16.2	76,189	30.1	22,458
Construction	13.3	61,699	14.7	102,903	18.2	41,204
Services	13.5	105,575	13.7	192,422	13.3	86,849
Wholesale Trade	13.5	56,499	13.4	76,224	13.0	19,725
Finance, Insurance, and Real Estate	12.2	38,645	12.5	62,045	13.1	23,400

Sources: [4, 5].

[a] Nonmetro share is defined as the percentage of total Southern employment in any industry which is located in counties over 50 miles from an SMSA.

[b] The "unclassified" category is omitted from the sub totals. Consequently they do not add up exactly to the figure for total nonfarm employment. In addition, *County Business Patterns* data exclude government, farming, domestic service, and self-employed workers.

First, looking at the major industrial groups (i.e., one-digit), the greatest shift was the clear tendency of manufacturing to move toward nonmetro labor markets. The nonmetro counties gained almost one out of every four new manufacturing jobs (23.4 percent) in the 1960's, thus increasing their share from 18.3 percent in 1959 to 20 percent 10 years later. Thus, along with the often-noted trend toward the suburbanization of manufacturing jobs, there occurred in the South in the 1960's a clear movement toward non-SMSA locations. Construction and transport, communications, and public utilities also showed the same pattern. The nonmetro share of the other one-digit sectors remained roughly the same.

Second, within the manufacturing sector two closely connected industries recorded a trend toward more metropolitan locations. The nonmetropolitan share of lumber dropped from 35.7 percent in 1959 to 32.2 percent by 1969. However, this was due not to an increase of lumber employment in the metro South, but rather to a slower decline in SMSA areas than in the nonmetro counties. The paper industry, however, recorded a greater gain in SMSA than in nonmetro labor markets, lowering the rural share from 24.9 to 22.9 percent.

Outside of lumber and paper, recorded declines by manufacturing industries in their nonmetro share were quite small (e.g., printing and publishing, —0.8 percent; instruments, —0.8 percent; and leather, —0.3 percent).

On the other hand, several industries recorded sizeable shifts toward nonmetro labor markets. The most dramatic of these were in electrical machinery and transportation equipment. For both of these the nonmetro share in 1959 was quite small: 9.6 percent for electrical machinery and only 3.5 percent for transportation. In both, *almost one out of every four added southern jobs in the 1960's occurred in nonmetro counties* (25.3 percent for electrical equipment and 23.4 percent for transportation equipment). Thus the rural share for the former jumped from 9.6 percent to 19.8 percent, and for the latter, 3.5 percent to 13.5 percent.

For two of the most nonmetropolitan industries (leather and apparel) the nonmetro share remained roughly the same. Consequently, nonmetro labor markets' growth in electrical and transportation industries occurred not only because they shared proportionately in the general Southern growth in these industries (as was the case with apparel), but also because there was a tendency to shift away from SMSA locations.

A sizeable shift also occurred in furniture, a fast-growth industry in the South. Twenty-five percent of added jobs were in nonmetro areas. Thus their share of 11.7 percent in 1959 rose to 16.9 percent in 1969.

Table 2. Ten-state South: nonmetropolitan share[a] of manufacturing industries, 1959–1969, manufacturing two-digit industries, arrayed by nonmetro share in 1969

Industry and SIC Number	1959 Nonmetro Share of Industry Jobs		1969 Nonmetro Share of Industry Jobs		Change, 1959–1969 Nonmetro Share of Industry Change	
	Percent	Number	Percent	Number	Percent	Number
Manufacturing	18.3	383,879	20.0	623,101	23.4	239,222
31-Leather and Leather Products	44.6	12,169	44.3	18,742	43.9	6,573
23-Apparel and Related Products	35.9	67,964	36.2	125,737	36.6	57,773
24-Lumber and Wood Products	35.7	67,088	32.2	61,854	−128.7	−5,234
28-Chemicals and Allied Products	21.1	31,697	25.4	51,961	37.5	20,264
26-Paper and Allied Products	24.9	24,142	22.9	27,401	14.5	3,259
30-Rubber and Plastic Products	17.6	4,866	21.9	14,235	25.0	9,369
36-Electrical Machinery	9.6	6,185	19.8	36,604	25.3	30,419
20-Food and Kindred Products	18.1	42,045	19.7	52,398	30.5	10,353
29-Petroleum and Coal Products	10.4	2,582	19.3	4,216	1634/ −2977[b]	1,634
39-Miscellaneous Manufacturing	16.0	3,340	17.7	6,872	19.6	3,532
25-Furniture and Fixtures	11.7	11,620	16.9	26,783	25.6	15,163
37-Transportation Equipment	3.5	3,125	13.5	24,426	23.4	21,301
32-Stone, Clay, and Glass Products	6.8	5,366	12.7	12,060	41.3	6,694
35-Nonelectrical Machinery	10.8	5,751	12.7	16,415	14.1	10,664
33-Primary Metal Industries	6.0	6,938	10.4	14,616	30.0	7,678
34-Fabricated Metal Products	6.8	5,971	10.0	15,174	14.4	9,203
38-Instruments and Related Products	9.9	1,620	9.1	1,343	17.0 of loss	−277
22-Textile Mill Products	7.6	37,058	8.8	47,923	19.0	10,865
27-Printing and Publishing	7.5	5,286	6.7	7,020	5.1	1,734
Administrative and Auxiliary	1.6	671	4.8	4,091	7.8	3,420
21-Tobacco Manufactures	0.9	440	1.7	761	321/ −3394[b]	321
19-Ordnance and Accessories	33.8	1,545	0.0	0	−4.2	−1,545

Sources: [4, 5].

[a] For definition of nonmetro share, confer footnote to Table 1.

[b] Nonmetro jobs increased although total industry employment in the South declined; thus tobacco jobs fell by 3394 in the whole South, but in nonmetro areas they increased by 321. Percentages were not calculated in such cases because the negative sign would be misleading.

Almost 40 percent of new chemical jobs were in nonmetro areas. Consequently the share increased from 21.1 percent to 25.4 percent.

Other industries recording sizeable increases in nonmetro share were stone, clay and glass products, primary metals, petroleum and coal products, and rubber and plastics. No other increases in nonmetro share over 3 percent were recorded, except for fabricated metal products (3.2 percent) and administrative and auxiliary employees (also 3.2 percent). However, both of these subsectors, despite the nonmetro increase, remain among the five most metropolitan industries in 1969.

Conclusions

The most common hypothesis is that the surplus labor pools of displaced farmworkers in the nonmetro South would attract mainly the lowest wage and most labor-intensive industries. Hence the nonmetro share of industries would be inversely proportional to the industry wage-level and directly proportional to labor-intensity. (It is known that the nonmetro South's share of such low-wage and more labor-intensive industry in the 1960's was greater than that of either the metro South or the U. S. as a whole) [2, pp. 158–165]. When the above nonmetro share hypothesis was directly tested for ranked correlation,[5] it was supported. The coefficient of rank correlation was .509, statistically significant at the 99 percent level ($t = 3.2$). However, the locational factors seem more complicated than the simple hypothesis suggests. Some of the leading industrial gainers in the nonmetro South in the 1960's were by no means the low-wage, labor-intensive firm of the usual stereotype. For example, the second and third largest net gainers of employment in the 1960's among manufacturing industries were electrical machinery and transportation equipment,[6] neither of which is a low-wage industry at the two-digit level. Perhaps Southern nonmetropolitan areas experience a two-stage process of development, in which the low-wage, labor-intensive firms of the first stage prepare a factory-trained labor force which then attracts the relatively higher-wage, more capital intensive firms of the second stage. A second hypothesis is that the surplus labor pools from agriculture are no longer a significant supplier of labor, and firms are moving into nonmetro areas to attract labor from more congested areas. However, whatever the full explanation may be, it is clear that no simple model of SMSA dominance which regards the nonmetro areas as almost totally lacking in manufacturing locational advantages can fit the observed industrial changes in the South in the 1960's.

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[5] Kendall's rank order correlation test was used. Labor-intensity and wage-levels in 1969 were combined into one ranking and correlated with the ranking by nonmetro share. References [6] and [3] provided the data.

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[6] Their combined net gain was 51,720 jobs—21.6 percent of the total manufacturing gain in nonmetro labor markets [2, p. 90].

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Comparative Advantage among African Coffee Producers*

Scott R. Pearson and Ronald K. Meyer

Relative comparative advantage is measured by contrasting country ratios of the domestic resource costs per unit of foreign exchange earned by exporting coffee to the exchange rate. Uganda, Ethiopia, and Tanzania have strong relative comparative advantages in coffee *vis-à-vis* the Ivory Coast, largely because of higher opportunity costs of Ivoirian factors.

Key words: **comparative advantage; coffee; domestic resource cost ratios; African agriculture.**

African producers of coffee are believed to be relatively efficient compared with other coffee growing nations and thus to enjoy an international competitive advantage in coffee production.[1] Since 1962, however, the African coffee exporters have not been able to exploit any such advantage fully because the International Coffee Agreement (ICA), of which they are signatories, places ceilings on the amounts of coffee that producing members can export to consuming members. Determination of comparative costs in coffee, therefore, could be important either (a) in aiding the allocation of country export quotas, if the ICA is renewed, or (b) in analyzing the likely distribution of future coffee export earnings, if the ICA is not renewed. In the absence of an agreement the lower cost countries could expand output, depress prices, and thereby decrease earnings of less efficient exporters.[2]

A complete answer to the question of African international competitiveness in coffee would require detailed data on coffee production and marketing costs in each of the African exporting nations and in each of the principal non-African competing countries. In view of the scarcity of such data for most coffee producing countries, it is not possible to undertake a full analysis of comparative advantage in coffee production. The more limited purposes of this paper are to take two important steps in assisting a later answer to this question: first, to suggest a suitable methodology which can be replicated as additional data are made available; and second, to apply the methodology in an analysis of comparative costs of coffee in four African countries —Ethiopia, Ivory Coast, Tanzania, and Uganda —for which sufficient information is extant. Succeeding sections of this paper deal with the methodological approach, the empirical analysis, and some concluding observations.

Methodology

As Chenery [6, pp. 19–25] has pointed out, a country has a comparative advantage in exporting a commodity if the social opportunity cost of producing a unit of the commodity—the value of all factors of production used to produce it in their best alternative employment—is less than the commodity's export price:

$$F \cdot E + D < P \cdot E \tag{1}$$

where

F = direct and indirect foreign factor costs per unit of output (in foreign currency),

E = exchange rate (local currency to foreign currency),[3]

D = direct and indirect domestic factor costs per unit of output (in local currency),

and

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[1] See, for example, Chudson [7, p. 405]. Gwyer [8, pp. 467–70] bases his analysis of coffee exports of Kenya, Tanzania, Uganda, and Brazil on an assumption that the African countries are low cost producers.

[2] The earnings of coffee exporting countries which did not increase output would decrease proportionately as well as absolutely if demand is not perfectly elastic with respect to price. For evidence of the price inelasticity of demand for coffee, see Maizels [11, p. 290], Rowe [12, pp. 11–12], and Wickizer [16, pp. 25–26].

[3] The appropriate variable is the shadow price of foreign exchange. Bacha and Taylor [1, especially pp. 214–17] provide a comparative analysis of alternative measures of the shadow price of foreign exchange and suggest a formula for the equilibrium exchange rate. However, in the empirical analysis below the actual exchange rate existing in the years in question was a reasonable approximation for the shadow price of foreign exchange [10, 13, 14, 15].

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P = price of the export per unit (in foreign currency).

A second definition, the domestic resource costs per unit of foreign exchange earned or saved (DRC), is equivalent to the first as a measure of comparative advantage:

$$DRC \equiv \frac{D}{(P-F)} < E. \tag{2}$$

Stated in this way, a country has a comparative advantage in the production of an exportable commodity if the ratio of the opportunity costs of total (direct and indirect) domestic factors used in each unit of production to the net foreign exchange generated per unit of the commodity (i.e., the export price less total foreign factors employed per unit of output) is less than the exchange rate.[4] This second definition, DRC, has been suggested and applied by Bruno to measure the comparative advantage of economic activities producing tradable goods and services within a single country.[5]

An adaptation of the DRC concept allows comparison among different countries of their relative degrees of efficiency in producing an identical exportable commodity. If each side of (2) is divided by the exchange rate, the criterion for comparative advantage becomes:

$$\frac{DRC}{E} < 1. \tag{3}$$

The "relative" comparative advantage of one country *vis-à-vis* another in a single commodity is obtained by comparing the DRC/E ratios, since DRC/E expresses the comparative efficiency of an activity within the domestic economy.[6] If the ratio of DRC to E for the first country is less than that for the second country, the former has a relatively greater comparative advantage than the latter in exporting the commodity in question.

Analysis

Cost data and results of the DRC analysis are presented in Table 1.[7] The data are drawn from research based on detailed field studies and can be considered reliable, subject to the usual difficulties in gathering valid statistical information in nearly all African (and other) developing countries.[8] The four countries considered in Table 1 accounted for more than one-half of the average value of coffee exports originating from Africa in 1967–1969 and approximately 13 percent of the total world value of coffee exports in that period [9, p. 17].

On the basis of the data presented, Uganda, with a DRC/E ratio of .33, was the most efficient of the four African coffee producers, followed quite closely by Ethiopia (.40) and Tanzania (.42).[9] Interestingly, the Ivory Coast, with a ratio of DRC/E of .75, lagged far behind. While all four countries had clear comparative advantages in exporting coffee, the first three appeared to have considerably stronger comparative advantages relative to the Ivory Coast.

Some light can be shed on the reasons underlying these differences by examining the input shares in total output of each of the four countries. Among the three more efficient countries, Ethiopia had the lowest share of on-farm ex-

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[4] In both definitions, it is assumed that factor costs reflect true scarcity values, external effects are accounted for, and variations over time in the major variables are considered [3, pp. 21–25; 5, pp. 548–49; 6, pp. 20–25].

[5] For descriptions of the DRC methodology, see Bruno [3, 5], and for applications to Israel, see Bruno [2, 4].

[6] The DRC/E ratio reflects marginal relations at a given point in time. To evaluate the effects of changes over time, in principle DRC/E should be calculated as a function of output over the relevant range, although in practice this calculation is not usually possible.

[7] Comparative advantage typically refers to the situation existing before any trade has occurred. The concept of comparative advantage is used here to examine the implications for alternative countries of changes in current trade restrictions. It is assumed that although trade has already taken place, further trade would occur given a relaxation of the restrictions. The reference point is the current position rather than the pretrade position.

[8] The most detailed information for the four countries considered is available for the Ivory Coast [14]. Data on the three other countries were obtained by doctoral candidates in the Food Research Institute, each a resident of the country being studied [10, 13, 15]. The underlying data in all four studies are drawn largely from standard, published government documents. Comparability among data categories in Table 1 has been achieved through detailed discussions with authors of the country studies.

[9] The available data measure average, rather than marginal, costs. Use of average cost data in calculating a DRC ratio is appropriate only if marginal and average costs are equal within the relevant range of output, i.e., if returns to scale are constant. The existence of scale economies, while unlikely to be large in coffee production and marketing in the four countries included in this study, would introduce an upward bias to DRC results based on average cost data. This bias would only be important in the analysis if countries were affected differentially, again an unlikely situation in the included countries.

Table 1. Costs of production, domestic resource cost ratios, and relative comparative advantage of coffee in four African countries

	(Millions of local currency or as indicated)			
	Ethiopia 1969	Ivory Coast 1967	Tanzania 1967–68	Uganda 1968–69
Volume of coffee exports (thousands of metric tons)	79.7	157.0	44.2	180.6
Gross output^a				
Millions of US$	61.6	91.9	35.3	96.6
Millions of local currency	153.9	22,971	252	690
	(100)	(100)	(100)	(100)
Marketing expenses	34.8	3,156	42	96
	(23)	(14)	(17)	(14)
Payments to government	14.4	8,100	33^c	127
	(9)	(35)	(13)	(18)
Gross farm income	104.7	11,715	177	467
	(68)	(51)	(70)	(68)
Intermediate inputs and hired labor	1.9	591^b	20	44
	(1)	(3)	(8)	(6)
Imputed labor and capital	28.3	13,501^b	43	116
	(18)	(59)	(17)	(17)
Residual rent	74.5	−2,337	114	307
	(48)	(−10)	(45)	(44)
Total resource costs^d	65.0	17,248	105	256
	(42)	(75)	(42)	(37)
Domestic resource costs	58.1	17,133	105	216
	(38)	(75)	(42)	(31)
Foreign resource costs	6.9	115	*	40
	(4)	(*)	(*)	(6)
DRC (local currency/US$)	.99 E$/$1	187 CFAF/$1	2.98 sh/$1	2.37 sh/$1
Exchange rate (local currency/US$)	2.5 E$/$1	250 CFAF/$1	7.14 sh/$1	7.14 sh/$1
DRC/Exchange rate	.40	.75	.42	.33

Sources: Ethiopia [15]; Ivory Coast [14]:Tanzania [13]; and Uganda [10].

( )—percentage share of gross output.

*—less than 1.

[a] Outputs for the indicated years are valued at 1968 prices, calculated from data on volume and value of output for 1968. Varying average unit values among countries reflect varietal and quality differences, principally much larger proportions of arabica in Ethiopia and in Tanzania and of robusta in Ivory Coast and in Uganda.

[b] Both imputed labor costs and hired labor costs are included in the entry for imputed labor and capital.

[c] This figure includes a surplus of 8, some of which is retained by farmers as residual rent.

[d] This entry is the sum of marketing expenses, intermediate inputs and hired labor, and imputed labor and capital.

penses, 19 percent, compared with 23 percent for Uganda and 25 percent for Tanzania. In contrast, marketing expenses were 14 percent for Uganda, 17 percent for Tanzania, and 23 percent for Ethiopia. Uganda, therefore, had the lowest share of total expenses, 37 percent; Ethiopia and Tanzania followed with 42 percent each. Foreign factor costs were of only minor significance in all three countries and were in no instance greater than 6 percent of the value of gross output. In spite of their identical cost shares, Ethiopia had a smaller *DRC/E* ratio than Tanzania because coffee in Ethiopia was more competitive relative to the average of all other Ethiopian tradable activities than was the case in Tanzania.

The cost picture in the Ivory Coast was significantly different. The total of on-farm and marketing expenses was 75 percent of the value of coffee output, more than twice that of any of the other three countries. Coupled with payments to government of 35 percent (also nearly double the level of any other country), the high share of expenses resulted in a negative residual rent to coffee land, an item which was positive and more than 40 percent of the value of gross output in each of the other three countries.[10] The ability to switch easily into another highly profitable export crop, cocoa, has caused the opportunity costs of domestic resources in he Ivory Coast to be much higher than those n the three countries in Eastern Africa.[11] In ddition, the international competitiveness of ther activities, on average, in the Ivory Coast ndoubtedly exceeds that of the average in each f the three other countries.[12] Hence, the relative omparative advantage of the Ivory Coast in roducing coffee is considerably less than that f Uganda, Ethiopia, and Tanzania, because the pportunity costs of Ivoirian domestic resources re relatively higher, and the other activities roducing tradable goods in the Ivory Coast re on average more competitive internationally than in the three other countries.[13]

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[10] The negative residual rent in the Ivory Coast could be attributed to a disequilibrium situation existing during the period in question.

Conclusion

The relative degree of comparative advantage among countries producing an identical export commodity can be measured by ranking the ratios for each country of the domestic resource costs per unit of foreign exchange earned for the commodity to the exchange rate; the country with the smallest ratio has the strongest comparative advantage. Uganda, Ethiopia, and Tanzania have strong relative comparative advantages in coffee with relatively small absolute differences among them. The Ivory Coast, however, has a significantly weaker competitive position in coffee, largely because of higher opportunity costs of domestic factors of production. Similar empirical analysis of the other African coffee exporters and, especially, of the principal Latin American producers of coffee is required before the relative degree of comparative advantage of the coffee exporting nations in Africa *vis-à-vis* the other major exporters can be ascertained.

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[11] No data are available on the opportunity costs of and devoted to coffee production. As a result, the com- arative advantage of countries with good alternative and uses is overestimated and that of countries with oor alternatives is underestimated. More study is re- uired before a definitive conclusion can be reached on he magnitude of bias introduced by not considering he opportunity cost of land. If this cost were included, he existence of an alternative cash crop, cocoa, which s more profitable than alternatives in the other three ountries, would accentuate the measured relative com- arative disadvantage of Ivoirian coffee.

[12] For a discussion of the Ivoirian economy and of lternatives to coffee production, see Stryker [14].

[13] With respect to the *DRC/E* ratio, the first influ- nce causes the numerator to be greater and the second causes the denominator to be smaller for coffee in the Ivory Coast relative to the other countries.

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First-Best and Second-Best Policies of Pricing an Imported Input: The Case of Fertilizer in Taiwan, 1950–1966*

ROBERT C. HSU

Under a government-peasant fertilizer-rice barter system in Taiwan, the use of chemical fertilizer is heavily taxed through a high fertilizer-rice exchange ratio. Important economic gains can be realized if the government lowers the tax on fertilizer input and raises, if necessary, the tax on rice output instead.

Key words: **pricing policy; fertilizer; Taiwan.**

THE THEORY of "first-best" and "second-best" policies has been the subject of many theoretical studies in the last two decades,[1] but empirical application of the theory has been meager. As is well-known, the traditional trade theory postulates that under perfect competition free trade is optimal. In the case of domestic distortions (divergences of the commodity price ratios from the corresponding marginal rates of transformation), Bhagwati and Ramaswami [2] have demonstrated that the optimum policy is a tax-cum-subsidy on domestic production, not intervention in foreign trade in the form of a tariff.

Ramaswami and Srinivasan [14] have analysed the case where the optimum policy is infeasible because the government has to collect a given amount of revenue by trade taxes alone. They have shown that if initially an imported input used to make exports is taxed while exports are free of tax or subsidy, welfare can be raised by abolishing the tax on that input and adjusting taxes on imports for home use to make up for the revenue loss. Furthermore, the optimal taxes on imports for home use will in general be unequal and will depend on the form of the welfare and production functions.

In this paper first-best and second-best policies of pricing imported chemical fertilizer in Taiwan are empirically studied to demonstrate the relevance and applicability of these theories under slightly different circumstances in a developing country—where a given amount of revenue is initially collected by a heavy tax on a primarily imported input, fertilizer, combined with a light tax on its major output, rice, which is exported as well as domestically consumed.

Pricing of fertilizer in Taiwan is suitable for the study for several reasons:

(1) The government-peasant fertilizer-rice barter system in Taiwan is unique. Fertilizer is under government monopoly—the government operates the importation, domestic production, and sale of fertilizer. The bulk of fertilizer is sold to rice-growing peasants in exchange for rice under a "fertilizer-rice barter system." The official price of fertilizer is given in terms of a fertilizer-paddy rice exchange ratio, that is, the number of kilograms of paddy rice required to exchange for one kilogram of each variety of fertilizer. The fertilizer-rice (barter) price ratio is set by the government at a high level, more than double the international price ratio, for the purpose of collecting a large amount of rice to feed government troops and employees.[2]

(2) There is an international trade relationship between fertilizer and rice. In the period under study the bulk of the fertilizer used was imported from Japan. In return, part of the rice output was exported to Japan and some other countries. Thus the domestic price ratio between fertilizer and rice can be studied along with the international price ratio.

(3) International prices of fertilizer and rice

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[1] For a survey of the literature, see Bhagwati [1].

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[2] The high price ratio is not designed to discourage the use of fertilizer in rice production, although it does have that effect. Through extension services, for instance, the government encourages peasants to increase their fertilizer application and the peasants are free to purchase as much fertilizer as they need from the government. For details of the fertilizer-rice barter system, see Hsu [11]. Besides controlling the fertilizer-rice price ratio, the government also regulates the retail price of rice. See Chen [3] for details.

are exogenous. Being a small trader internationally in both fertilizer and rice, Taiwan has no influence over their prices.

First-Best Policy

The model

The fertilizer-rice price ratio that the government should charge depends on the objective of the government. If the maximization of agricultural income is the objective and if there are no domestic distortions, the optimum domestic fertilizer-rice price ratio should equal the domestic marginal rate of transformation in production between fertilizer and rice and the corresponding international price ratio (transportation cost included), as trade theory would suggest.

In this paper it is assumed that maximization of foreign exchange is the objective of the government with regard to the pricing of fertilizer. The reason is that foreign exchange has been a bottleneck in the economic development of Taiwan in the period under study, and various government actions do indicate that this assumption is realistic.[3] A foreign exchange maximizing objective has been pointed out by many development economists, particularly McKinnon [13] and Chenery and Strout [4]. Foreign exchange is badly needed to import capital goods and raw materials for which there are no domestic substitutes. In symbols, in any year

(1)

$$\text{Maximize} \quad W = P^e_r(R - R_c) - P^m_f(F - \bar{F}_d)$$

where

W = foreign exchange earnings of rice export net of import cost of fertilizer.

P^e_r = export price of rice from Taiwan to Japan, f.o.b.

R = total rice output, estimated as a function of the level of fertilizer used, F.[4]

R_c = total rice consumption of the economy, estimated as a function of rice output, R.[5] There exists a certain

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[3] This assumption is supported by the following facts, (1) in all but two years (1963, 1964) in the period under study, the value of imports exceeded that of exports considerably; (2) in the 1960's the government imported some lower-grade rice from South-east Asia so that more higher-grade rice could be exported, in spite of objections from domestic consumers; and (3) in spite of high production cost the government has been attempting to develop the domestic fertilizer industry in order to save foreign exchange.

[4] Total rice output is determined by rice acreage and rice yield. Rice acreage is exogenously given in the model because it is found that rice acreage in Taiwan does not respond to changes in price of rice, of competing crops, or of fertilizer, but is determined by the availability of irrigated land which in turn is determined by the differential rates of urban expansion and irrigation development.

Rice yield is estimated from both time series data and the results of fertilizer experiments contained in Chu [6]. Various functional forms have been tried with the amount of fertilizer elements used and a time trend (in the case of time series) as the variables. The effect of abnormal weather is eliminated by deleting from the time series the years in which major typhoons and flooding took place. Although a weather index can be developed, it will require a separate study which is beyond the scope of this paper.

From the rice yield functions, the marginal rice product of fertilizer (R') in Table 1 is obtained. For details see Hsu [11, pp. 61–69]. For a discussion of the various functional forms that can be used for a yield function, see Heady and Dillon [9, pp. 73–107].

[5] Total rice consumption of the economy consists of rice consumption of the agricultural sector, that of the nonagricultural sector, and that of the government. Rice consumption of the agricultural sector is determined by the size of agricultural population and its per capita demand for rice. The former is exogenously given in the model while the latter is estimated as a function of (a) the price of rice relative to the prices of the goods which peasants buy, including fertilizer; (b) per capita rice output as a proxy for per capita agricultural income —because the study is interested only in the effect of an increase in rice production on rice consumption and because, other things being equal, agricultural income is a function of rice output; and (c) a time trend reflecting changes in tastes and dietary habits.

Similarly, rice consumption of the nonagricultural sector is determined, for example, by the size of nonagricultural population, its per capita income, and price of rice. However, since the price of rice is controlled by the government and cannot be predicted from supply and demand alone, it is assumed that changes in the price of fertilizer will not affect the rice consumption of the nonagricultural sector. In other words, the latter is exogenously given in the model. The amount of rice which the government needs for consumption is fixed by the size of its armed forces and employees and thus is exogenously given also.

Consequently, the marginal rice consumption of the economy with respect to rice output is equal to that of the agricultural sector. The latter is estimated in various functional forms based on both dietary survey results contained in Yeh [16] and time series. The results are inconclusive because of data limitations (see Hsu [11, pp. 70–88] for details). Consequently, a range of variation (0–0.4) is used for the value of marginal rice consumption with respect to rice output, R_c', in Tables 1–3 below.

Confer also studies on the demand for food by Stone [15] and Girshick and Haavelmo [7]. The effect of the changing age composition of the population over time on per capita demand for food can be eliminated by using an age-specific consumption scale to convert popupositive minimum below which R_c cannot fall.

$R - R_c$ = exportable rice surplus.

P_f^m = import price of fertilizer from Japan to Taiwan, c.i.f.

F = total amount of fertilizer used in rice production, estimated as a function of the fertilizer-rice price ratio in a demand function for fertilizer.[6]

$\bar{F}_d$ = domestically produced fertilizer, given in any year.

There exists an institutional constraint on the pricing of fertilizer in Taiwan. This constraint arises because the government needs to collect annually a given amount of rice to feed its armed forces and employees by means of the fertilizer-rice barter with the peasants and of a land tax on rice output payable in kind. Thus the maximization of foreign exchange earnings given in formula (1) is subject to the constraint that in any year

$$(2) \qquad R_g = F(P_f/P_r) + tR \geqslant \bar{R}_g$$

where

R_g = total amount of rice collected by the government.

P_f/P_r = domestic price ratio between fertilizer and rice.

t = agricultural land tax rate on rice output.

$\bar{R}_g$ = the amount of rice which the government needs annually for feeding its troops and employees.

In equation (2), $F(P_f/P_r)$, total amount of fertilizer used times the domestic fertilizer-rice (barter) price ratio, gives the total amount of rice collected by the government from fertilizer-rice barter. Since the excess of the domestic fertilizer-rice price ratio over the international one is a tax on the use of fertilizer, $F(P_f/P_r)$ includes both the tax revenue on fertilizer and the import cost of fertilizer in terms of rice.[7] The term tR is the land tax revenue on rice output. Equation (2) is expressed in terms of government rice collection rather than in terms of total revenues or agricultural tax revenues because the former represents a closer approximation of the actual constraint encountered by the government of Taiwan. Because of this constraint, the optimum fertilizer-rice price ratio which satisfied equation (1) may not be feasible under certain circumstances unless taxation on rice output can be increased, as will be seen below in the "second-best policy" section.

When equation (2) is not binding, the condition for maximizing foreign exchange earnings can be obtained by differentiating equation (1) with respect to fertilizer and setting it equal to zero:

$$(3) \qquad \frac{\partial W}{\partial F} = P_r^e(R' - R'_c R') - P_f^m = 0,$$

i.e.,

$$R'(1 - R'_c) = P_f^m/P_r^e$$

where

R' = marginal rice product of fertilizer

and

R'_c = marginal domestic rice consumption with respect to rice output.

Thus foreign exchange earnings will be maximized when the level of fertilizer application is such that the marginal exportable rice surplus due to the last unit of fertilizer applied equals the international fertilizer-rice price ratio. Let this level of fertilizer used be designated by F^*. The fertilizer-rice price ratio which will induce peasants to use F^* amount of fertilizer is the optimum or "first-best" fertilizer-rice price ratio, designated by $(P_f/P_r)^*$. Here it is assumed that the peasants are responsive to changes in the fertilizer-rice price ratio, but not that they maximize their earnings from fertilizer use and rice production. In fact, evidence suggests that the peasants

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lation size and per capita consumption into those of adult-equivalent [15, p. 416].

[6] Amount of fertilizer used in rice production is estimated from time series in a demand function for fertilizer. Two models are used: a "traditional" demand model and a "Nerlovian adjustment" model. In the traditional model, the demand for fertilizer is a function of the fertilizer-rice price ratio, rice yield lagged one period, and a time trend reflecting the peasants' increasing familiarity with, and willingness to use, chemical fertilizer. In the Nerlovian adjustment model, rice yield lagged one period and time trend are replaced by the quantities of fertilizer used in the previous period. Prices of other inputs are not included in the demand functions because of the unavailability of data.

From the demand functions for fertilizer, the marginal demand for fertilizer with respect to fertilizer-rice price ratio and the price elasticity of demand for fertilizer, given in Table 2, are obtained. For details see Hsu [12]. Confer also Griliches [8] and Heady and Yeh [10] for the demand for fertilizer in the United States.

[7] To the extent that the domestic price of rice is also controlled by the government and is below its equilibrium level, the difference between domestic and international fertilizer-rice price ratios will be due partly to the lower domestic price of rice.

have not maximized their earnings from rice production, nor have they used fertilizer to their best advantage, given the domestic prices of fertilizer and rice.[8] In other words, the marginal rice product of fertilizer is larger than the price ratio between fertilizer and rice ($R' > P_f/P_r$), as can be seen below in Table 1.

$(P_f/P_r)^*$ was estimated in the following way. Let *k* be the average degree of underadjustment of the peasants to the marginal rice product of fertilizer such that

$$(4) \qquad R' = k(P_f/P_r)$$

$$\text{or} \qquad k = R'/(P_f/P_r).$$

Thus at $(P_f/P_r)^*$, substituting equation (4) into equation (3), one obtains

$$(5) \qquad k(P_f/P_r)^* \, (1 - R'_c) = P_f{}^m/P_r{}^c$$

$$\text{i.e.,} \quad (P_f/P_r)^* = \frac{1}{k(1-R'_c)} \cdot \frac{P_f{}^m}{P_r{}^e}$$

$$= \frac{P_f/P_r}{R'} \cdot \frac{1}{1-R'_r} \cdot \frac{P_f{}^m}{P_r{}^c}.$$

Equation (5) gives the optimum fertilizer-rice price ratio in terms of parameters that can be estimated.

Empirical results

In Table 1 the values of $(P_f/P_r)^*$ for various values of R' and R'_c are presented. The first two estimates of R' for each fertilizer are based on time series while the third estimates are based on results of experimental farms. Some observations can be made from Table 1:

(1) All the values of $(P_f/P_r)^*$ are much lower than the actual domestic fertilizer-rice price ratio, indicating that the latter should be reduced from the standpoint of maximizing foreign exchange earnings.

(2) When R'_c is zero, the values of $(P_f/P_r)^*$ are even lower than the international price ratio, indicating that the use of fertilizer should be subsidized. In this case, the condition for maximizing foreign exchange earnings becomes identical with that for maximizing agricultural income.

Table 1. Optimum fertilizer-rice price ratio (average of 1950–66)[a]

	R'	k	R'_c	$(P_f/P_r)^*$
A. F = nitrogen	4.62[b]	1.39	0	1.01
			.1	1.12
$P_f/P_r = 3.32$			.2	1.26
			.3	1.44
$P_f{}^m/P_r{}^e = 1.4$			.4	1.68
	4.51[b]	1.36	0	1.03
			.1	1.15
			.2	1.29
			.3	1.47
			.4	1.72
	3.44[c]	1.04	0	1.35
			.1	1.49
			.2	1.68
			.3	1.92
			.4	2.24
B. F = phosphorus	4.08[b]	2.29	0	0.48
			.1	0.53
$P_f/P_r = 1.78$			.2	0.60
			.3	0.69
$P_f{}^m/P_r{}^e = 1.1$			.4	0.80
	3.75[b]	2.10	0	0.52
			.1	0.58
			.2	0.66
			.3	0.75
			.4	0.80
	1.88[c]	1.05	0	1.05
			.1	1.16
			.2	1.31
			.3	1.50
			.4	1.75

[a] All rice is converted to polished rice equivalent, and all fertilizer to pure element equivalent.

P_f/P_r = actual domestic fertilizer-rice price ratio.
$P_f{}^m/P_r{}^e$ = ratio of import price (c.i.f.) of fertilizer from Japan to export price of rice (f.o.b.) to Japan.
R' = marginal rice product of fertilizer.
k = degree of under-adjustment of the peasants [see equation (4)].
R'_c = marginal consumption of rice with respect to rice output.

See footnotes 4 and 5 for sources and estimation procedure for R' and R'_c.

[b] Based on time series on average fertilizer application and rice yield.

[c] Based on results of experimental farms.

(3) The degree of underadjustment of peasants, *k*, is generally much lower in the use of nitrogen than in the use of phosphorus. This is consistent with the fact that the peasants have longer experience in the use of nitrogen fertilizer and that they have a traditional preference for it.

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[8] Traditionally the peasants have taken it for granted that all fertilizers should turn leaves green as ammonium sulphate does. Any fertilizer that has no such visible effect is considered poor. Furthermore, nitrogen fertilizer, in the form of ammonium sulphate, was the first chemical fertilizer introduced to the peasants in 1928. Other varieties were introduced much later. Thus the peasants have had longer experience with the use of nitrogen fertilizer. See Chu [5, p. 46] and Hsu [12].

(4) For each fertilizer, the degree of underadjustment is consistently higher for estimates of R' based on time series than for those based on results of experimental farms. Since the conditions of experimental farms are different from those of the average farms, estimates based on time series are believed to be more reliable.

Second-Best Policy

The constraint

The optimum or first-best price ratios derived above may not be feasible because of the constraint given in equation (2) that the government collects a certain minimum amount of rice annually from the fertilizer-rice barter and from the land tax on rice output. To find out the conditions under which equation (2) will be binding, one first needs to know the marginal change in government rice collection when the fertilizer-rice price ratio is lowered. It is obtained by differentiating equation (2) with respect to P_f/P_r, holding t constant:

$$(6)\quad \frac{\partial R_g}{\partial(P_f/P_r)} = R'_g = F + F'\,(P_f/P_r) + tR'F'$$

$$= F + F'\,(P_f/P_r + tR')$$

where

R'_g = marginal government rice collection with respect to P_f/P_r, holding t constant.

F' = marginal demand for fertilizer with repect to P_f/P_r.

t = agricultural land tax on rice output.

R$'$ = marginal rice product of fertilizer.

The sign of equation (6) depends on the marginal demand for fertilizer, F', assuming t and R' remain unchanged. Two different models of demand for fertilizer were estimated with different results. In the case of nitrogen, the predominant fertilizer element used, F' ranges from —32 to —16.6 (see Table 2).[9] According to calculations given in Table 2, if the absolute value of F' is higher than 27 (or the elasticity of demand for nitrogen is higher than 0.945), then rice collection constraint represented by equation (2) will not be binding, for the total amount of rice collected from the fertilizer-rice barter will be increased after the price reduction. In this case the optimum price ratios given in Table 1 are all feasible, and reducing the fertilizer-rice price ratio toward the optimum level will have the effect of increasing both government rice collection and foreign exchange earnings.

On the other hand, if the absolute value of F' is lower than 27 (or the elasticity of demand for nitrogen element is lower than 0.945), R'_g will be positive. Under such circumstances, government rice collection will decline when the fertilizer-rice price ratio is reduced *and* t is not increased, even though rice output will be increased.

With the first-best policy it was shown that foreign exchange earnings will be increased when P_f/P_r is *reduced toward* its optimum levels. Thus, dividing W in equation (1) by P_r^e so that the foreign exchange earnings are expressed in rice unit, and then differentiating W/P_r^e with respect to P_f/P_r, one obtains

$$(7)\quad \frac{\partial(W/P_r^e)}{\partial(P_f/P_r)} = \frac{\partial W_r}{\partial(P_f/P_r} = W'_r$$

$$= F'\,[R'\,(1 - R'_r) - P_f^m/P_r^e]$$

where

W_r =foreign exchange earnings in terms of rice

and

W'_r =marginal foreign exchange earnings in terms of rice with respect to P_f/P_r.

W'_r is negative according to the results in Table 2.

Dividing equation (7) by equation (6), one obtains the marginal rate of transformation between W_r and R_g, i.e., between foreign exchange earnings in rice unit and government collection of rice. The policy-makers can then weigh the increase in W_r against the loss in R_g in deciding how far P_f/P_r should be reduced.

In Table 2 a range of variation for the value of W'_r/R'_g in the case of nitrogen was estimated with t being held constant at 4 percent. Since R'_g is negative when the absolute value of F' is higher than 27 (or when the elasticity of demand for nitrogen is higher than 0.945), W'_r/R'_g will be positive and there will be no transformation to speak of. It is only when R'_g is positive that there will be a trade-off between W_r and R_g.

Taxation on rice output

Note that in Table 2 R'_g is positive for some values of F' because t is being held at 4 percent. In other words, government rice collection de-able 2. Marginal rates of transformation between W_r and R_g (average of 1950–1960)[a]

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[9] See footnote 6 and Hsu [12] for the models. From the regression results obtained it is difficult to say which estimate is better. In the absence of more data, these estimates will be regarded as constituting a range of realistic numbers for the purpose of illustrating the economic analysis in this paper.

	F'	E_f	R'	R'_g	R'_c	W'_r	W'_r/R'_g
$F = 95$	−32.0[b]	1.12	4.62	−17.0	.2	−73.5	
$t = .04$					.3	−58.6	
$P_f^m/P_r^e = 1.4$					.4	−44.0	
$P_f/P_r = 3.32$			3.44	−16.0	.2	−43.4	
					.3	−32.3	
					.4	−21.4	
	−27.0	0.945	4.62	0.0	.2	−62.1	
					.3	−48.6	
					.4	−37.8	
			3.44	1.5	.2	−36.4	−24.2
					.3	−27.3	−18.2
					.4	−17.8	−11.8
	−25.8	0.9	4.62	4.0	.2	−59.3	−14.8
					.3	−46.4	−11.6
					.4	−36.1	−9.0
			3.44	6.0	.2	−34.8	−5.8
					.3	−26.0	−4.3
					.4	−17.0	−2.8
	−16.6[c]	0.58	4.62	46.8	.2	−38.2	−0.82
					.3	−30.6	−0.66
					.4	−23.0	−0.49
			3.44	37.7	.2	−22.5	−0.60
					.3	−16.8	−0.45
					.4	−11.1	−0.29

[a] Rice is measured in terms of polished white rice equivalents.

F' = average kilograms of nitrogen element used per hectare per year.

t = average agricultural land tax rate.

F = marginal demand for nitrogen with respect to P_f/P_r (in kilograms per hectare).

E_f = elasticity of demand for fertilizer; derived according to the formula $E_f = -\dfrac{P_f/P_r}{F} \cdot \dfrac{dF}{d(P_f/P_r)}$.

R'_g = marginal government rice collection with respect to P_f/P_r.

W'_r = marginal foreign exchange earnings in rice unit with respect to P_f/P_r.

ee footnote 6 for source and estimation procedure.

[b] Estimated from an "adjustment model" of demand function for fertilizer.

[c] Estimated from a "traditional model" of demand function for fertilizer.

lines for some values of F' when P_f/P_r is reduced ecause of the assumption that the tax rate on ice output cannot be increased. However, if it is easible to raise t, then in equation (2) there ill be two independent variables, P_f/P_r and t, nstead of just one. Therefore when P_f/P_r is reuced toward its optimum level, one can increase simultaneously to keep R_g constant.

The concomitant increase in t that is required o keep government rice collection constant when $_f/P_r$ is reduced can be calculated in the follow- g way. Let superscript "o" denote the original agnitudes of the various variables and "1" the ew magnitudes, and P_f/P_r and t are the two inependent variables to be changed. The following quality will hold if R_g is to remain constant:

(8)

$$F^o(P_f/P_r)^o + t^oR^o = F^1(P_f/P_r)^1 + t^1R^1.$$

From equation (8), t^1 can be calculated.

In Table 3 the price elasticity of demand for nitrogen was assumed to be 0.55 and the values of t^1 calculated according to formula (8) with P_f/P_r reduced to some selected optimum levels given in Table 1. Changes in rice output and exportable rice surplus, for example, are also given in Table 3, all expressed in terms of percentage changes from their original magnitudes.[10] The

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[10] In calculating Table 3 it is assumed that marginal rice product of fertilizer (R') remains constant. For large reductions in P_f/P_r, this will not be true due to a

Table 3. Effects of reducing P_f/P_r to some optimum levels[a]

R'	$(P_f/P_r)^*$	$\frac{d(P_f/P_r)}{(P_f/P_r)^o}$	$\frac{dF}{F^o}$	$\frac{dR}{R^o}$	R'_e	$\frac{dR_e}{R_e^o}$	t
4.62	1.12	−66%	36.3%	3.6%	.1	46%	13.1%
	1.26	−62	34.0	3.4	.2	38.4	12.3
4.51	1.47	−56	30.8	2.8	.3	27.3	11.2
	1.72	−48	26.4	2.4	.4	20.1	9.9
3.44	1.92	−42	23.1	1.6	.3	16.0	8.9
	2.24	−33	17.9	1.3	.4	10.6	7.5

[a] F = nitrogen.
$E_f = 0.55$.
Superscript "o" = the original magnitudes of the variables.
"d" = changes in the variables concerned.
R = total rice output.
R_e = exportable rice surplus.
t = agricultural land tax on rice output.

price elasticity of 0.55, just below the low estimate of 0.58 given in Table 2, was chosen for ease of calculation as the lowest possible estimate to show the highest possible extent to which t has to be raised to keep government collection of rice constant when P_f/P_r is lowered. As can be seen from Table 2 and formula (8), the higher the elasticity of demand for fertilizer, the smaller the needed increase in t until the elasticity reaches 0.945 when t does not have to be raised at all.

Thus when the price elasticity of demand for fertilizer is 0.55, whether or not the first-best optimum price ratios between fertilizer and rice are feasible will depend on whether or not it is feasible to raise the land tax rate on rice output to the new levels given in Table 3.

If it is infeasible to raise t to these new levels, the second-best policy will be to raise it as much as possible and then lower P_f/P_r accordingly so that government collection of rice remains constant. These fertilizer-rice price ratios are second-best price ratios, designated by $(P_f/P_r)^{**}$. To calculate these second-best price ratios, one has to know the extent to which the tax rate on rice output can be raised. This is, of course, a political question for which economists claim no special expertise. Once it is given, however, the second-best price ratio can be calculated from formula (8) for each and every estimate of the price elasticity of demand for fertilizer.[11] In Table 4, these price ratios have been calculated for the hypothetical cases where t can be raised from 4 percent to 5 percent, 6 percent, 7 percent, and 8 percent respectively. The elasticity of demand for fertilizer is again assumed to be 0.55, the lowest possible. By varying the elasticity within its possible range, other second-best price ratios can similarly be computed.

The raising of t and the lowering of P_f/P_r to levels given in Table 4 represent a shift in the agricultural tax structure from taxation on fertilizer input to taxation on its rice output. Results of this shift will be the following:

(1) The peasants pay the *same* total amount of rice to the government as before and receive a greater amount of fertilizer for rice production.

(2) As a consequence, rice output, consumption, and export will all be increased. Foreign exchange earnings will not be maximized but will be increased. Additional fertilizer imported will be paid for with part of the increased rice export earnings.

These results are the outcome of a greater participation in foreign trade and a more efficient allocation of resources in accordance with the internationally given prices, made possible by a reduction in government intervention in foreign trade (taxation on the use of imported fertilizer). Naturally, greater benefit will result when the cause of the trade intervention is removed and the domestic fertilizer-rice price ratio is reduced

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large increase in the use of fertilizer. Thus the accuracy of the figures in Table 3 decreases with the increase in price reductions.

[11] Alternatively, these prices can be obtained by solving equations (1) and (2) by the constrained maximization method; that is,

$$\text{Maximize } V = P_r^e(R - R_c) - P_f^m(F - \bar{F}_d) + \lambda(F\,P_f/P_r + tR - \bar{R}_g).$$

By solving the first-order conditions for the maximization of V, the second-best price ratios can be obtained.

Table 4. Second-best fertilizer-rice price ratios[a]

	$(P_f/P_r)^{**}$			
R'	$t = 5\%$	$t = 6\%$	$t = 7\%$	$t = 8\%$
4.62	2.78	2.33	2.02	1.71
4.51	2.78	2.36	2.02	1.71
3.44	2.80	2.39	2.04	1.74

[a] F = nitrogen.
$E_f = 0.55$.
$P_f/P_r = 3.32$.

to the optimum levels discussed in the first-best policy section above.

Conclusions and Limitations

For the sake of simplicity the analysis was conducted in terms of the fertilizer-rice price ratio, a land tax on rice output, and government collection of rice from the agricultural sector. Since the excess of the domestic fertilizer-rice price ratio over the international one is a tax on the use of imported fertilizer input while government collection of rice constitutes part of government revenue in general, the analysis could have been undertaken in terms of an import tax on fertilizer input, a land tax on rice output, and government revenue in general, although some of the mathematical equations would have been more complicated.

Welfare can be increased if taxation on the use of an imported input is reduced. Further, the optimum level to which it should be reduced will be lower, the higher the degree of underadjustment on the part of the peasants, i.e., the greater the domestic distortions in production.

As an approximation, if the elasticity of demand for input is numerically greater than unity, total government revenue will be increased after the reduction in the price of input.[12]

If price elasticity of demand for the input is numerically less than unity, taxation on output has to be increased to keep total revenue constant. However, as long as it is possible to raise the tax rate on output, it will be desirable to reduce the price of input toward its optimum level. In other words, a lower tax on input combined with a higher tax on output is superior to a higher tax on input combined with a lower tax on output, for the peasants will be better off in terms of output while the government will not be worse off in terms of revenue collected. At the same time export earnings can be substantially increased.

The favorable effects of such a shift in the tax structure are dependent on the fact that use of fertilizer in rice production in Taiwan is productive in the sense that its marginal physical product is much higher than the international fertilizer-rice price ratio. If use of fertilizer is not productive, the conclusion will be different. The dividing line between productiveness and unproductiveness of an input, however, depends on the objective function of decision-makers. If the objective is to maximize foreign exchange earnings, the criterion for productiveness is that its marginal exportable surplus in terms of its output be greater than the international price ratio between input and its output. If the objective is to maximize income, the criterion is that the marginal physical product of input be greater than the corresponding international input-output price ratio.

Given the objective function, if the use of an input is not productive due to over-use or to soil or climatic conditions, it would be better to have a higher tax on the use of input and a lower tax on output so that input and foreign exchanges will not be wasted. If unproductiveness is due to lack of complementary inputs like insecticide or water or due to lack of experience or knowledge on the part of the peasants, the above conclusion will still hold if other appropriate measures are also taken simultaneously to remove the cause of unproductiveness.

The major conclusion of this study agrees with that of Ramaswami and Srinivasan's study [14] on optimum tax structure and is also consistent with Bhagwati and Ramaswami's [2] conclusion that where domestic distortions exist, the optimum policy is a tax-cum-subsidy on domestic production, but not a tariff on imports.

Finally, it is important to note the limitations of the study. First of all, the analysis in this paper is that of partial equilibrium. It assumes, for example, that changes in the agricultural sector will not significantly affect the non-agricultural sector and the latter's foreign exchange earnings in the short run. This may not be true in reality.

Furthermore, although the objective or welfare function assumed in the study is believed to be a realistic one for the pricing of fertilizer from the government's point of view, it is a model of partial analysis in at least two ways: (1) As the government faces other bottlenecks in the economy and has other policy objectives, the possible incongruity of the objectives may impose additional constraints on the objective function used in this paper. (2) Since the government's objective function is not necessarily identical with that of consumers or peasants, a gain in welfare in the narrow sense of the government's objective function may entail some welfare loss on the part of the consumers. For example, an increase in rice export earnings due to an austerity campaign to restrict the domestic consumption of rice or due to a drive to substitute PL480 wheat for rice in the consumers' diet will most likely cause some welfare loss to the consumers.

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[12] While this is the case with fertilizer-rice in Taiwan, the general validity of this statement will naturally depend on the forms and parameters of the various functions used. This is also true of the general validity of the next paragraph where the elasticity is numerically less than unity.

Within these limitations, the study has highlighted an area of potential economic gains and provided a preliminary analytical framework for further investigation and policy considerations.

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Chile's Experiments in Agrarian Reform: Four Colonization Projects Revisited*

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Agrarian reform has variable effects on its beneficiaries. Some make considerable income progress while others stagnate. A number of factors are involved in this relative success or failure.

Key words: **agrarian reform; income distribution.**

OPTIMISTIC SOCIAL SCIENTISTS who write on agrarian reform suggest that incomes of beneficiaries will rise above what farm laborers receive; these income increments will be used to acquire equity in capital and increase consumption. The net effect, over time, will be manifest in salutary effects on the employment problem. Furthermore, the distribution of income should be more equitable than before and production should increase [see, for example, 2, 3, 4, 6, 7, 8, and 9]. Not much data has been presented to support these claims.

Analyzing four settlements in Chile's Central Valley located from Santiago to Linares and established by a private foundation, the Instituto de Promoción Agrícola (INPROA), the author concluded in 1964 that, "Reform tends to raise the incomes of campesinos immediately. . . . the income of new landholders [families] was, on the average, increased two or three times under the [new] system" [8, p. 202].[1]

This statement was qualified in two ways: the sample group was studied soon after the reform took place; and four colonies constituted a rather small sample.

This paper attempts to overcome the first difficulty; its purpose is to provide panel design data which are often lacking in discussions of agrarian reform and colonization and to allow the reader to generate some hypotheses that might be worthy of further investigation and analysis. Thus, data on families living on all four farms were gathered again in 1970.[2] Both 1964 and 1970 were considered by local agronomists as "normal agricultural years." The key questions concerning some of the economic issues are:

(1) How are net family and per capita income and their distribution different in 1970 from the situation in 1964?
(2) How do colonists spend their income?
(3) How has labor use changed over the study period?
(4) What factors are associated with "economic success"?

In 1964, three post-reform tenure patterns were being used on the four settlements. Table 1 describes both these patterns and those found in 1970, the principal income sources, and the pattern of interviewing used.

Even though no joint farming remained on these settlements in 1970, one cannot conclude *ipso facto* (as some analysts are wont to do) that the production co-op tends to fail in Chile. The strongest limited purpose co-ops in 1970 were on Los Silos and San Dionisio where the beneficiaries participated in group farming upon settlement. These co-ops helped members to market crops and buy inputs, and they assessed members for "common expenses" like repairing irrigation works. Some bookkeeping and a few technical assistance functions were also performed by the cooperative.

By 1970 the land reform foundation had greatly reduced its technical assistance on all of the farms, but it remained guarantor of most crop loans that the co-op received from public agencies and re-loaned to members. Hence, a technician visited the settlements several times

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[1] For more detail on 1964 than is possible to present here, see [8].

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[2] The crop years in Chile run from May 1 to April 30. Since harvesting runs from January to April depending on latitude and crop, 1963–64 will often be referred to as "1964" and 1969–70 will be referred to as "1970."

Table 1. The setting

	Land Tenure Pattern, 1964	Land Tenure Pattern, 1970	Development of the Cooperative, 1964 to 1970	Principal Income Sources, 1970	Interviewing Pattern
Los Silos	A production cooperative but each settler also had a small plot of his own to raise home consumed and marketable crops.	Individual family-sized farms	A fairly strong service cooperative	Dairy	Number family heads interviewed 1964 = 15 Number reinterviewed 1970 = 15 Number chosen randomly to interview 1970 = 1[a]
Las Pataguas	Individual family-sized farms	Individual family-sized farms	Fairly weak service cooperative	Field crops	Number family heads interviewed 1964 = 19 Number reinterviewed 1970 = 16 Number chosen randomly to interview 1970 = 3
San Dionisio	Sharecropping system in which original large fields were not split. Land supplied by land reform foundation but operating costs and net income were split 50-50. Designated member committee in charge of each field. Settlers also could rent small plot of sugarbeets of their own.	Individual family-sized parcels	A fairly strong service cooperative	Mainly field crops; some animals	Number family heads interviewed 1964 = 14 Number reinterviewed 1970 = 8 Number chosen randomly to interview 1970 = 7[a]
Alto Las Cruces	Same as San Dionisio	Individual family-sized parcels	Fairly weak	Field crops	Number family heads interviewed 1964 = 8 Number reinterviewed 1970 = 6 Number chosen randomly to interview 1970 = 2

[a] One colonist more was interviewed in 1970 than in 1964 because the universe had grown.

a year although he had little contact with most of the settlers.

Methodology

The questionnaire used in 1970 allowed direct comparisons with the 1964 data. All data were adjusted to *escudo* (the unit of Chilean currency)[3] values in 1970. The inflator was based on the agricultural wholesale price index (which was very similar, over the period examined, to the general wholesale price index). Had the consumer price index been used, income differentials over time would have been more marked (calculated from [1, p. 139, and 5, Cuadro 25, p. 39]).

Table 1 shows the number of heads of families interviewed each year. Some of the original interviewees could not be found. In that case, the total sample was completed in 1970 by selecting colonists randomly from the remaining universe. The study groups included 56 families in 1964 and 58 in 1970.[4] The analysis below will at times utilize the entire sample as a measure of the entire colony's progress; at other points it will utilize only the 45 settlers who were interviewed both in 1964 and 1970, to trace most clearly the changes in the situation of individuals over time.

Income Analysis

Overall gross income per hectare rose from E°1,873 to E°3,240[5] on the four colonies over the study period—a rate of about 10 percent a year. Overall agricultural production in Chile rose along an irregular path at a rate less than half of that [10, p. 3]. Mean net family income (total gross income minus operating expenses) rose on all four settlements when 1970 was compared to 1964.[6] Gross family income (sales of family labor and product plus in-kind consumption) averaged E°36,148; off-farm earnings made up about 4 percent of that figure.

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[3] In early 1970, $1 U. S. equaled about 15 Chilean escudos (E°), but this was the official rate; in the black market many more escudos were traded for the dollar.

[4] Disaggregated cost and output data were gathered, bit by bit, and combined into income figures.

[5] Tabular supportive data may be found in Land Tenure Center Paper 97 bearing the same title as this paper.

In 1970 San Dionisio had the highest net family income of the four colonies, but Alto Las Cruces showed the highest gain in net. The family income gain on Las Pataguas was rather small. Overall mean family income rose 42 percent.

If these settlers had received the government-set minimum wage (E°12 from January 1 through December 31, 1970), had worked 320 days during the year, and if only the head of the household was engaged in wage labor, each family would have received the equivalent of E°3,840, about 15 percent of their actual mean earnings. If earnings to capital and land are subtracted from 1970 beneficiary earnings, the average family would show returns to labor of about double that made by a wage laborer.

Family size grew during the study period. So, on a per capita basis mean net income rose by only 5 percent.

Distribution of income

When net family income on the 45 families from which data were secured in 1964 and 1970 (Table 2) was rank ordered and aggregated by thirds (call them terciles), the income distribution in that year is indicated. These categories being maintained in 1970, the percentage received by the top tercile drops and that of the bottom tercile rises. Indeed, the bottom tercile earned in excess of the average of the middle tercile in both 1964 and 1970. However, when income is rearranged into terciles by level of income in 1970, income for the top group rises and for the bottom group falls. This indicates a growing tendency toward family income inequality, but also considerable mobility. This observation also holds when per capita income is analyzed.

When the crop producing settlements are considered together (call them "1") and Los Silos, the dairy farm, is considered by itself (as "2"), it is obvious that a good bit of this differential performance is caused by what happened on Los Silos. After dissolution of the production cooperative, a few colonists were able to acquire animals, but most were not (and some bought animals that subsequently died). On "1," income accruing to the top and bottom thirds drops slightly as a percentage of aggregate net income when 1970 is compared with 1964. On Los Silos the share in the aggregate net family income of the lowest tercile dropped from 18 percent to a negative number while the share of the top group rose by about 30 percentage points to over 80 percent of aggregate net income. What happened was that a few mistakes in dairying lead to the loss of an animal, and an inability to make a fairly sizable initial payment can lead to nonacquisition in the first place. Crops, on the other hand, permit a wider range of error—a person may have a good crop or a poor one but seldom no crop at all. Also, seeds and fertilizers are easier to acquire because they are divisible; investment in cattle does not have this characteristic.

Of the 45 original families in 1964 who were interviewed again in 1970, 23 remained in the same net family income tercile in 1970 as in 1964; since seven of these remained in the bottom tercile, they probably can be regarded as "hard core poverty." Over half of those in the bottom tercile in 1970 were Los Silos settlers. Ten settlers showed upward mobility and 12 dropped to a lower tercile. There is some tendency for families to remain in their same relative position in the income spectrum, but one can also argue that there is an element of fluidity and settlers are not entirely "locked" into their relative position. Some analysts writing on reform assume that all beneficiaries progress more or less in equal measure. That is not true; some make considerable income progress while others stagnate.

Again considering the entire sample, the development paths of the four colonies when net family income and egalitarianism were considered fell into several categories. San Dionisio and Alto Las Cruces showed a fairly high rate of growth between 1964 and 1970. But it took place in a more egalitarian fashion on San Dionisio (where the bottom half of the income receivers earned 39 percent of that income accruing to the top half in 1964 and 51 percent in 1970) than on Alto Las Cruces (where the comparable figures were 34 and 27). Las Pataguas and Los Silos exhibited slower rates of net family income growth. Las Pataguas seemed to be on a more egalitarian trajectory (with the bottom half of the income receivers getting 26 percent of the income in

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[6] For purposes of these comparisons we assume that in 1964 all income and operating costs on the sharecropped land (San Dionisio and Alto Las Cruces) accrued to the beneficiaries.

Table 2. Distribution of net family income by terciles (45 families studied in 1964 and 1970)

Terciles	Aggregate Net Family Income			Percent of Total per Year		
	(1) 1964	(2) 1970 (All families in their 1964 terciles)	(3) 1970 (Income rearranged into thirds by level of income in 1970)	(4) Percent in each tercile in 1964 (Col. 1)	(5) Percent in each tercile in 1970 (same people) (Col. 2)	(6) Percent of each tercile in 1970[a] (rearranged) (Col. 3)
	E°	E°	E°			
1	559,750	556,205	697,734	63	53	66.5
2	227,267	225,592	320,590	25	22	30.5
3	107,417	265,040	28,513	12	25	3
Totals	894,434	1,046,837	1,046,837	100	100	100

[a] Gross income by terciles was distributed 57 percent, 29 percent, and 14 percent.

1964 and 50 percent in 1970) than Los Silos. (The bottom half of the latter earned 47 percent of all income in 1970, but half of this third averaged a negative income.) Thus, it seems possible to have both stagnation and growth with egalitarianism—or without it.

Equity value in capital

Besides measuring income, another way well-being was measured was the extent to which a farmer accumulated wealth over the study period. Indeed, stock of capital owned gave a better welfare measure than income since what a farmer owned in 1970 was a cumulative function of all income generated in the six-year period. While it is possible to argue that even in a panel design some of the received income is transitory, this assertion is more difficult to make if, say, highest income receivers have also acquired the most capital. The best proxy measure of wealth available here is investment in movable farm capital. Land is not used since most had not yet made significant amortization payments. Such capital as fruit trees, an improved building, and irrigation works were very much in evidence, but they proved too difficult for farmers to evaluate. Furthermore, there appeared to be a high positive correlation between both of these omitted categories and movable capital.

On the average, overall mean family equity in movable farm capital rose 263 percent when 1970 is compared to 1964. Table 3 utilizes only the 45 colonists studied both in 1964 and in 1970. It demonstrates that when the movable capital terciles of 1964 are used to aggregate 1970 capital, the share of the top group fell while that of the bottom rose. The same observation about net income was made in the preceding section and provided some check on these data. Capital purchased by all terciles increased appreciably in the study period. When 1970 movable capital was aggregated into terciles, an almost imperceptible change in shares occurred over the study period. To check further on the accuracy of 1970

Table 3. Equity in movable capital by tercile for the 45 families studied both in 1964 and 1970

Terciles	Movable Capital Aggregated by Terciles			Percentages of Total in Each Tercile		
	(1) 1964	(2) 1970 (All individuals in their 1964 tercile)	(3) 1970 (Capital rearranged into 1970 terciles)	(4) Percent in each tercile in 1964 (Col. 1)	(5) Percent in each tercile in 1970 (Col. 2)	(6) Percent in each tercile in 1970 (Col. 3)
	E°	E°	E°			
1	408,707	837,864	938,134	70	61.5	69.0
2	114,465	319,474	308,599	20	23.5	22.5
3	56,778	205,306	115,911	10	15	8.5
Total	579,950	1,362,644	1,362,644	100	100	100

income data, movable capital was aggregated by the settlers who made up the 1964 income terciles (see Table 2). It was found that 19 settlers fell into the same tercile while 21 fell into the immediately preceding or succeeding third. Only five were highly divergent cases. Of the seven labeled as "hard core poverty" in the previous section, four appeared in the bottom 1970 capital tercile; three were in the middle group.

How is income spent?

Marketable surplus and off-farm expenditures.—Does agrarian reform result in increased demand for consumer and investment goods? The best measurement of potential demand available is total disposable income—total net family income less all consumption in kind. It was impossible to calculate percent rise on Los Silos because total disposable income was a negative number in 1964 and members lived on the subsidy that came from the land reform foundation. Considering only the other colonies, mean overall disposable income in 1970 was 91 percent greater than in 1964.

Investments and debts.—A major question to be solved by the settlers and the land reform foundation is this: will beneficiaries pay off current debt on production credit and land? As Table 4 reveals, families made some purchases of capital on their own account during the 1970 crop year—usually when they harvested or sold some meat or milk.

As was the case in 1964, the average settler seems to overestimate his consumption. But the conclusion that the settler purchased a mean value of E°4,052 worth of capital on his own account and consumed the remainder of his family income seems inescapable. This means that payments were not made toward either institutional production credit or land in 1970 by this "mean" settler, and he found himself with E°10,515 in debt (Table 5) to be carried over into 1971.

When settlers were regarded as individuals, it was found that only about one-quarter were able to make a significant contribution toward land and capital that came from official sources (not on "own account"), a result similar to the case reported for 1964 [8].

While a farm subsidy may be absolutely essential for some years after the agrarian structure is reformed, money cannot indefinitely be loaned and not repaid. It seems that settlers are regarding loaned funds as a "gift." Were this a country-wide agrarian reform, such a mass attitude could easily bankrupt the public coffers, contribute substantially to inflation, and/or result in a complete cut-off of government aid to the peasant sector. One should remember that the campesino sector has been discriminated against for long periods of Chilean history and may, at this juncture, deserve a windfall. But if this were repeated country-wide (and there are strong indications that this happened under both the Frei and the Allende reforms), the government would be subsidizing a small group of beneficiaries while leaving the non-beneficiaries further behind than ever.

In 1964 colonists at the arithmetic mean utilized an equivalent of about E°16,000 of their net family incomes for consumption items; they spent about E°21,000 in 1970. About half of their consumption in 1964 was "in kind" products grown on the farm; the figure dropped to about one-third in 1970. It would seem that if settlers are really expected to make payments on credits, consumption will have to be trimmed and production will have to increase still further.

Labor use

In the 1964 study it was found that "in 1963-64 the four fundos averaged 12 percent more

Table 4. Mean amount remaining to pay for cash consumption and self-estimates of cash consumption, 1970

	(1) Total disposable income	(2) Investment on a family's own account throughout the year	(3) Amount remaining for consumption (1 minus 2)	(4) Self-estimated consumption
	E°	E°	E°	E°
Los Silos	15,810	3,999	11,811	14,096
San Dionisio	19,948	4,195	15,753	12,867
Las Pataguas	15,102	2,572	12,530	17,019
Alto Las Cruces	17,697	6,848	10,849	13,308
Overall	17,007	4,052	12,955	14,527

Table 5. Amount indebtedness in 1970 to be carried over into 1971 by the average settler[a]

	Principal due on production credit	Land payment due	Total debt
	E°	E°	E°
Los Silos	11,998	1,594	13,592
San Dionisio	8,427	2,122	10,549
Las Pataguas	7,098	1,575	8,673
Alto Las Cruces	5,504	1,440	6,944
Overall	8,805	1,710	10,515

[a] Arithmetic mean on each colony.

families than before the reform [8, p. 202]." That figure had risen to nearly 20 percent in 1970, and the full resident capacity of the fundos had been realized.

In 1964 several standards of average labor use were used, and it was found that by using any of them the beneficiaries of land reform appeared to be utilizing labor to a point where its wage bill exceeded the marginal value of the product. The following was concluded:

> One way of raising net income [of the settlers] might be to cut back on the amount of hired labor used until it is possible to intensify the operation. This means that individuals would have to become more efficient. . . . The defect of this recommendation is that one way effects of a reform can be spread to a larger group is through employing labor. Calling for a cut in labor supply reduces this beneficial effect of reform. On the other hand, once the farm is worked more intensively . . . [the beneficiary] should be better able to employ the superabundant labor which exists more productively than at present. [8, p. 203]

Total labor use per hectare was little changed from 1964 to 1970. Indeed, the data show a slight drop in labor application per hectare. While capital, operating expenses, and land rose from 35 percent of total input costs to 58 percent (imputing a labor charge to work by the operator and other unpaid hands), labor dropped from 65 percent of input costs in 1964 to 42 percent in 1970. The most marked change, however, is the drop in hired labor by over half—from 22 man days per hectare to 10 man days per hectare. Since all colonies showed a decline, this trend probably implied that settlers became more entrepreneurial (at least they admitted to becoming more "cost conscious" during the study period). Probably they realized that contracting labor beyond the point where the marginal value of its product equals the wage bill merely runs up operating costs and eats into net income. On Los Silos in 1964 contracted labor was paid for out of co-op funds. But by 1970 hired labor had to be paid by individual campesinos. Where labor costs began to impinge on individuals rather than the entire group over the study period, the drop in amount of hired labor used and the corresponding rise in amount of family labor that was applied was most marked.

In addition to a group that may have stagnated at the bottom of the income ladder on the colonies, another group that may not have benefited from this reform is the local hired labor. Of course it is possible that the group has found other, more remunerative employment since the reform. This is unlikely, but it is a point that was impossible to test.

Why Were Some Colonists Successful?

What were the factors—to a greater or lesser extent manipulatable by the settlers—that accounted for the fact that some settlers had more income than others in 1970? Trial multiple regression runs in which four dependent variables were regressed on a number of independent variables that could be theoretically justified left the analyst with the model described in Table 6, Line 1.

The dependent variable is x_1 = 1970 gross income.

The independent variables are listed below along with some theoretical justification for inclusion when necessary:

x_2 = a dummy indicating whether a settler lived on Las Pataguas.

x_3 = a dummy indicating whether a settler lived on Alto Las Cruces.

x_4 = a dummy indicating whether a settler lived on Los Silos.

x_5 = age of husband, 1970. The mean age of male household heads was 45, but the distribution was skewed to the older age brackets. One would imagine that, on balance, age would be negatively related to gross income.

x_6 = number of people in the household. One could hypothesize that the more people living together, the more gross income they would need. Presumably, they would also have the necessary labor force available to produce it.

x_7 = education of husband. Education ranged from 0 to 11 years with a mean of 2.6 years. Years of education were used as a proxy for enlightened management.

Table 6. Estimated coefficients from regression equations for (X_1) gross income, 1970 (group of 45 studied in 1964 and 1970)[a]

Colony	Constant	Dummy Las Pataguas (X_2)	Dummy Alto Las Cruces (X_3)	Dummy Los Silos (X_4)	Age of Husband (X_5)	Number of People in Household (X_6)	Education of Husband (X_7)	Total Male Work Days (X_8)	Equity in Animals (X_9)	Fertilizer and Seed Costs per Hectare (X_{10})	Crop Hectares (X_{11})	R^2
All Colonies	−2192.3 (14237.5) −1.54	−8236.3 (8152.7) −1.01	−394.11 (10718.3) −.04	−13748.0 (11049.6) −1.24	175.9 (157.6) 1.12	2357.0 (992.5) 2.4**	2372.0 (1176.5) 2.02***	1.09 (8.4) .13	.78 (.19) 4.2*	6.4 (2.7) 2.3***	3419 (567) 6.03*	.75
All Colonies Except Los Silos	−5944.0 (12120.3) −.49						2566.3 (1479.1) 1.74	10.7 (9.2) 1.2	−.03 (.54) −.06	8.8 (11.0) .80	4001 (713) 5.6*	.70
Los Silos	−14073.3 (25703.1) −.55						−120.8 (2128.4) −.06	−4.05 (28.3) −.14	.92 (.30) 3.08*	7.1 (3.4) 2.1****	11126.9 (10018.4) 1.1	.74
Los Silos	2738.1 (8022.2) .34								.70 (.20) 3.5*	7.9 (2.8) 2.8**		.70

[a] Cell structure: Regression coefficient
(Standard Error)
t.

* Significantly different from zero at the 1 percent level.
** 2 percent level.
*** 5 percent level.
**** 10 percent level.

x_8 = total male work days, a proxy for amount of effort.
x_9 = equity in animals, a value figure which closely correlated with value of animals in inventory, E^c.
x_{10} = fertilizer and seed costs per hectare, a proxy for amount of yield increasing inputs per hectare, E°.
x_{11} = number of crop hectares.

The regression equation using all of these variables was capable of explaining 75 percent of the total variation in the dependent variable.

The following conclusions may be drawn from this analysis: (1) Age of the household head and total effort based on a measure of days worked are not statistically important in determining variation in gross income given the other variables considered. (2) Crop hectares and number of animals owned were highly significant while education of the husband, number of people being supported, and yield increasing inputs per hectare were less significant. (3) The most manipulatable variables are probably yield increasing inputs (and short-term credit available per hectare which was fairly highly correlated with inputs) and equity in animals. An investment of E°1 in fertilizer and seed returned E°6.40 in gross income per hectare during 1970 and an investment of E°1 in livestock yielded a gross of E°.78 during the year.

These results suggested that there might be a fundamental difference between the three colonies which depended on crops for the bulk of their income and the colony which depended on dairy animals. When the non-dairy settlements were considered separately (Table 6, Line 2), the number of seeded hectares became very important while animal equity faded into insignificance. When Los Silos was considered by itself (Lines 3 and 4), the opposite situation prevailed and yield increasing inputs per hectare became somewhat significant. This last observation provides some justification for the Inter-American Bank loan for dairy cattle which will be reflected in 1971 income on Los Silos. Recalling an earlier section, however, it must be remembered that a dairy enterprise may be more conducive than one which is more dependent on crops to developing an inegalitarian pattern of income distribution.

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An Analysis of the Impact of Manure Disposal Regulations on Dairy Farms

MUHAMMAD ASHRAF AND ROBERT L. CHRISTENSEN

State regulations concerning animal waste disposal can be satisfied by the adoption of alternative manure disposal systems. A linear programming analysis of 25 dairy operations in Massachusetts shows that significant reductions in farm income and changes in optimum farm plans result when these systems are imposed upon the dairy business.

Key words: **manure disposal; dairy; farm income; opportunity cost.**

THE DETERIORATION of environmental quality in the United States has created a growing public concern for the natural environment. The demands of the public for improving the quality of the environment have initiated public legislation restricting and/or controlling the waste disposal activities of the producing and processing sectors of the economy. The 27 states producing 94 percent of the beef output and 82 percent of milk production now have water quality standards and/or administrative codes which are applicable to management of livestock wastes [6]. Environmental restrictions affecting livestock operations are generally specified in terms of disposal period, disposal site relative to populated areas and water sources, slope of land, and rate of manure application.

According to some of these restrictions, dairy operations in the Northeast (the major agricultural sector) may be prohibited from the practice of spreading manure daily. However, alternative manure disposal systems have additional investment costs and peak labor demands during the busy spring and fall periods of the year [1, 3, 5]. Direct investment costs in alternative manure disposal systems can be estimated [1, 2, 5] rather easily. To focus only on this dimension, however, results in an incomplete and perhaps erroneous assessment since it fails to consider properly the impact related to use of the labor resource. This paper is thus directed to the estimation of economic implications to the dairy business of adopting alternative manure disposal systems which may be dictated by regulations designed to reduce water pollution.

A standardized linear programming model adapted for dairy farming in Massachusetts [8] was used as a method of analysis. This model was expanded to incorporate the choice of an appropriate method of manure disposal system.[1] A second adaptation pertains to the choice of a least cost fertilization program for forage crops from a combination of manure and inorganic fertilizers. An expanded version of the linear programming model may be expressed algebraically as follows:

$$\text{Maximize} \quad \sum_{i=1}^{n} P_i X_i = \sum_{i=1}^{r} P_i X_i - \sum_{i=r+1}^{s} P_i X_i - \sum_{i=s+1}^{n} P_i X_i$$

subject to

(1) $AX \leqslant B$
(2) $X > 0$

where

- P_i refers to price or return or cost per unit of the ith product.
- X_i refers to the ith unit of product or commodity produced, bought or sold or transferred in a production process.
- $i = 1$ to r refers to livestock and crop production processes.
- $i = r + 1$ to s refers to various commercial fertilizer analyses considered for purchase in the model.

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[1] Among the alternative manure disposal technologies (including physical conversion and biological treatment methods), the conventional land spreading method is the least costly. However, the conventional disposal method in its existing form may contribute to the nutrient pollution of surface waters. The results of various soil science studies suggest that nutrient pollution from animal manures could be reduced with the provision of storage facilities during the winter period and then spreading on the cropland during the spring period [4, 7]. Similarly during the summer crop growing period, if land is not vacant, manure could be stored and spread in fall before frost and snow season. The second modification pertains to the incorporation of manure in the soil at an appropriate interval to achieve the complementary effects of reducing nitrogen losses to the environment and preserving the nutrients for crop production.

$i = s + 1$ to n refers to alternative manure disposal systems included in the model.

A refers to the $M \times N$ matrix of input-output coefficients.

B refers to an $M \times 1$ vector of amounts of fixed farm resources available or resource constraint levels.

X refers to an $N \times 1$ vector.

The Aij matrix in the model contains 43 rows and 63 columns. There are 36 rows of quantitative and non-quantitative constraints for fixed resources related to crop and livestock activities, and 7 control rows pertaining to commercial and organic nutrients and quantities of manure. Input vectors for the alternative land spreading manure disposal systems[2] were composed of coefficients expressing investment costs, seasonal labor requirements, quantities of manure, and organic nutrients.

The stacking and liquid storage methods of manure handling were imposed on the benchmark dairy farm organization to observe the impact on production levels, costs, and income. In the first series of computer runs, freedom of choice was limited to one disposal system at a time to investigate the impact of each disposal technology. A case study sample of 25 dairy farms with model herd sizes of 50, 100, and 212 milk cows was selected.[3]

Opportunity Costs of Adopting Alternative Manure Disposal Systems[4]

The adoption of either a stacking or liquid storage manure disposal system resulted in a reduction in farm income as compared to a daily spreading system. Adoption of a liquid storage system caused a larger reduction in farm income than a stacking system due largely to increased manure volume and amortization of the liquid system. Furthermore, the reductions in farm income were found to be inversely related to the capacity of manure hauling machinery included in each system. The results presented in the following sections are for the optimal sized spreading unit (which in most cases was the largest unit).

Free stall barns, herd size, and disposal system

The opportunity cost per cow (reduction in farm income) of imposing a stacking or liquid system on a free stall system was highest on large farms, followed by small and medium farms respectively (Table 1). Depending upon the unique resource endowment of cropland and labor, some of the small farms had reductions in their farm income as great as those observed on large farms. The performance of sub-systems of alternative disposal methods with varying sizes of dairy herd appeared to be similar. Incorporation of plowing operations in stacking or liquid systems of manure disposal created a significant

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[2] Land spreading manure disposal systems are defined in terms of storage alternative, size and type of hauling machinery, and method of application to cropland. These alternatives are then classified as manure handling systems both in terms of practices and technologies. Two storage methods of stacking and liquid storage were included in this study. Spreading manure involves the size of the spreader and the period between spreading and incorporation of manure in the soil. Spreader size determines the number of loads and, as a consequence, most of the seasonal labor time required to perform the hauling function. The time lag between spreading and incorporation in the soil influences the quantity of nitrogen available for crop use after volatilization and surface runoff losses.

Among the various manure spreaders available, three sizes were selected. They were 105 bushels, 175 bushels, and 320 bushels for stacking systems and 1,500 gallons, 2,100 gallons, and 3,000 gallons for liquid systems. Time lags for manure incorporation were added to each of the sub-systems. The three lag periods for stacking systems were 1 day, 4 days, and seasonal interval (seasonal interval refers to the period between crop harvesting in fall and planting in spring). However, with liquid systems a fourth possibility exists. Immediate plowing under of manure is possible with small and medium size tank wagons as they are available with plow-down attachments. This is not the case for the largest size considered, and a separate plowing operation would have to be undertaken with time lags similar to those of stacking systems.

[3] Sample farms consisted of 16 free stall and 9 stanchion dairy systems. Free stall systems included 3 small, 6 medium, and 7 large sized dairy herds. Stanchion systems included 6 small and 3 medium sized dairy herds.

Sizes used in the analysis were 57, 105, and 212 cows for small, medium, and large free stall system farms, respectively, and 49 and 98 cows for small and medium stanchion system farms, respectively.

[4] Opportunity cost discussed in this section is estimated under a fixed supply of farm labor. Skilled farm labor is a limiting factor on most of the commercial dairy operations, particularly during the periods of spring and fall. Part-time help during these periods may not be accessible due to the non-availability of school age labor and unwillingness of the casual labor to accept an extremely seasonal chore such as manure disposal at the market wage rate. The real value of labor diverted for manure disposal, therefore, seems to be higher than the wage rate. However, we did observe the impact of relaxed supply of seasonal farm labor which showed a favorable effect on the level of opportunity cost.

Table 1. Opportunity cost of adopting alternative manure disposal systems on different sizes of free stall and stanchion dairy farms[a]

	Stacking Systems		Liquid Systems	
Opportunity Cost	Manure Not Plowed Under	Manure Plowed Under	Manure Not Plowed Under	Manure Plowed Under
		Dollars		
FREE STALL FARMS				
Small Farms (57 cows)				
Per Farm	565	1271	1890	2430
Per Cow	10	22	33	43
Medium Farms (105 cows)				
Per Farm	825	1676	3217	4353
Per Cow	8	16	31	41
Large Farms (212 cows)				
Per Farm	3535	6245	8202	10905
Per Cow	17	29	39	51
STANCHION FARMS				
Small Farms (49 cows)				
Per Farm	—	448	—	1514
Per Cow		9		31
Medium Farms (98 cows)				
Per Farm	1028	1478	2825	3268
Per Cow	10	15	29	33

[a] Opportunity cost as defined here refers to the reduction in farm income from the benchmark situation due to the adoption of stacking or liquid systems. The benchmark situation (not shown) was a comparable daily spreading system. Figures have been rounded off to nearest dollar.

effect on the opportunity costs involved. The inclusion of plowing operations in stacking systems resulted in about twice as large an opportunity cost per cow as systems not including plowing operations. In the case of liquid systems, opportunity costs were about one-third greater for plowing than for non-plowing.

Stanchion barns, herd size, and disposal system

The cost impact of imposing an immediate plow-down requirement on the manure disposal operation was of lesser magnitude for stanchion housing situations. The optimum plans of the small farms indicated that disposal systems in conjunction with plowing operations would be preferred. The added value of nutrients derived through incorporating the manure in the soil implicitly exceeds the combined marginal cost of labor and direct operating cost of plowing. These farms find it relatively economical to recycle the manure nutrients for crop production. The net result of these factors is a lower opportunity cost per animal. This is not to suggest that the lower opportunity cost would give the small dairy herds a comparative advantage. Rather, the comparatively lower costs involved on the small farms may still be high enough to make them marginal farms or even force them out of business. Also, on the large stanchion systems of 98 cows, the difference in opportunity cost within the subsystems is not as wide. Both of the above differences arise from the fact that the availability of, or the conversion of part of the cropland into, pasture ameliorates the manure disposal problem. However, if the acreage base becomes similar, the difference in opportunity cost attributed to housing system becomes less evident.

Changes in Cropping Program and Disposal System

The adoption of alternative manure disposal systems produces certain quantitative and qualitative changes in the "crop mix" and thus in animal feeding. These changes are necessary to minimize the opportunity cost. In the Northeastern United States, major forage crops are corn, alfalfa, clover, and various other grasses. Hay crops are perennial, and the main resource concern is the requirement for harvest labor which is distributed throughout the period from late spring to early fall. Silage corn, in contrast to hay crops, has heavy labor requirements during rather narrow time periods for planting in spring and harvesting in early fall. Manure disposal systems designed to abate water pollution also require intensified use of labor during spring and early fall and thus aggravate the peak work loads of these periods.

As a consequence of competition for the labor input between silage corn and manure disposal activities, the proportion of land allocated to corn was reduced on all sizes of dairy farms according to the optimal farm plans (Table 2). The acreage released from corn becomes available for forage crops such as pure alfalfa and/or alfalfa grass mixes. However, these cropping plan adjustments created some imbalance in the feed nutrients produced. The decreased supply of net energy associated with reduced corn acreage was met by an adjustment in the dairy ration.

On small and medium free stall farms, stacking or liquid systems without plowing produced comparatively smaller changes in cropping plan. About 9 percent of the acreage formerly in corn was converted to hay production. When plowing down of manure was made a part of the disposal system, about 19 percent of the corn acreage was converted to hay crops. Structural changes on large farms were similar. Disposal systems not requiring immediate plow-down resulted in a reduction of 13 percent in corn acreage, and systems requiring immediate plow-down resulted in 20 percent of corn acreage being replaced by hay crops.

While the large stanchion farms showed changes in their cropping plans similar to those found in free stall systems, small farms experienced very little adjustment in the crop acreage distribution. A reduction of only 2 percent in corn silage acreage was estimated and this, in turn, resulted in 7 percent increase in the hay crop acreage.

Effect on Replacements and Herd Size

The imposition of alternative manure disposal systems also produces changes in the number of heifer calves to be raised on the farm. The impact varies according to herd size and type of disposal system. All of the sample farms utilized the opportunity of reducing the manure volume via the reduction in youngstock numbers (Table 3). The additional cost of manure disposal for heifers seems to exceed the cost advantages associated with raising the replacement stock of the farms rather than buying from outside sources. This conclusion is, of course, largely determined by the assumptions of the model with respect to productive abilities of purchased versus raised animals.

Table 2. Changes in major forage crops associated with alternative manure disposal systems on different sizes of free stall and stanchion dairy farms

		Stacking Systems		Liquid Systems	
Item	Daily Spreading (Benchmark)	Manure Not Plowed Under	Manure Plowed Under	Manure Not Plowed Under	Manure Plowed Under
	Acres	—Percent Changes Over Benchmark—			
FREE STALL FARMS					
Small Farms (57 cows)					
Silage Corn	53.3	—10	—18	—11	—19
Alfalfa-Grass	59.4	9	16	10	17
Medium Farms (105 cows)					
Silage Corn	66.7	—7	—19	—10	—21
Alfalfa-Grass	66.5	7	19	10	21
Large Farms (212 cows)					
Silage Corn	135.0	—12	—20	—14	—21
Alfalfa-Grass	78.0	21	35	24	37
STANCHION FARMS					
Small Farms (49 cows)					
Silage Corn	35.0	—	—2	—	—2
Alfalfa-Grass	12.0		7		7
Medium Farms (98 cows)					
Silage Corn	72.0	—11	—21	—10	—20
Alfalfa-Grass	48.0	16	30	15	30

Table 3. Proportion of replacement heifers raised on the farm under different manure disposal systems on various sizes of free stall and stanchion dairy farms

Category of Farm	Daily Spreading (Benchmark)	Stacking Systems: Manure Not Plowed Under	Stacking Systems: Manure Plowed Under	Liquid Systems: Manure Not Plowed Under	Liquid Systems: Manure Plowed Under
FREE STALL FARMS					
Small Farms (57 cows)	100	50	29	43	21
Medium Farms (105 cows)	46	11	11	15	11
Large Farms (212 cows)	27	10	0	3	0
STANCHION FARMS					
Small Farms (49 cows)	100	—	58	—	58
Medium Farms (98 cows)	46	8	4	3	4

Growth of large farms may be constrained by manure handling regulations requiring the adoption of stacking or liquid systems. The optimum plans of some of the large dairy farms entailed a reduction of herd size of about 5 percent with disposal systems not requiring immediate plowdown and in the range of 8 percent to 11 percent with the systems combined with plowing. This does not mean that these herd sizes would actually be reduced but that the real cost of system adoption is too high to allow expansion of herd beyond those levels.

Summary

Nutrient pollution of surface waters from animal sources is a major public concern. Alternative systems of manure disposal (such as liquid storage or stacking) could be utilized to reduce the pollution effect. Such changes result in investment costs 3 to 5 times higher than daily spreading systems. By intensifying competition for scarce labor time during spring and fall periods, these systems also affect the cropping plan and the growth of the dairy business. Reductions in net farm incomes are estimated to be in the range of $10 to $29 per cow with the adoption of stacking systems and $33 to $51 per cow for liquid systems. Small sized farms of 50 cows and medium sized farms of 100 cows experienced significantly smaller reductions in their farm incomes as compared to large farms of 212 cows. Stanchion dairy operations, which normally have 100 cows or less and have more pasture land, experience relatively little adjustment in optimum plans and impact on farm incomes as compared to free stall farms.

The nature and magnitude of opportunity cost consequences discussed above is predicated on the assumption that farmers would attempt to optimize their farm organization. These costs would be greater if a farmer chose a sub-optimum disposal system and/or was unable to make appropriate adjustments in farm resource use. However, the selection of an optimal disposal system might be dictated by non-economic factors such as slope of farm land, soil type, amount of precipitation, and the present level of water pollution. The choice of a particular system may be subject to other pollution criteria as well. Once a particular set of manure disposal regulations is imposed and a given farm is identified, it is then possible to specify a system which would conform to these regulations and have minimum income impact. In this paper an attempt was made to identify several possible manure disposal systems and to measure the costs which would be incurred by dairy farmers if adopted.

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Fertilizer Response Information and Income Gains: The Case of Potatoes in Peru*

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Yield response to different levels of fertilizer on various soils is estimated by a generalized response function. Average new income generated by use of optimum levels is estimated at over $800 per hectare. The social gain to Peru is estimated to be as much as $50 million annually.

Key words: **fertilizer; potatoes; Peru.**

Technological change is frequently associated with the discovery of new material inputs, such as seed varieties and new inventions. New income streams can also be generated by the discovery of new information about the use of existing inputs. An example is the case of fertilizer use. As new seed varieties and pest controls are discovered, yield response to fertilizer changes and new fertilizer response data can lead to income-generating changes in the use of fertilizer. Furthermore, the size of income streams generated in this manner will depend upon the techniques used to extract information from the fertilizer response data.

New income streams, whether generated by new material inputs or by new information, will be appropriated by individual producers initially, but only temporarily. In competitive industries such as agriculture, the income streams will eventually be completely passed on to consumers if the supply of all inputs is perfectly elastic. The purpose of the study reported here is to estimate the size of new income streams which can be generated by increased use of fertilizer on potatoes in Peru.

The Economic Model

The objective is to estimate the size of new income streams which can be realized by the discovery and use of new information, specifically new information about the response of potatoes to fertilizer. However, as Hirshleifer [7, p. 569] notes, Nature's secrets will not be autonomously revealed but must be extracted by man. Even after fertilizer response data are generated, the amount of information extracted will depend upon man's analytical ingenuity. This study examines the new income which can be generated by changing from current levels of fertilizer use (near zero) to each of three alternative levels. The first alternative consists of those levels of fertilizer currently being recommended by the Peruvian Ministry of Agriculture. These recommendations are based on classic response analyses of each of a number of response experiments. The other two alternatives are based on a generalized response analysis in which the data from all experiments are pooled. One set of recommendations is generated for each soil based on its soil test, and a second "blanket" recommendation is derived for all soils regardless of soil test.

Short-run increases in producers' income

In the short run, the expected new annual income from some higher level of fertilizer use on a given soil is the value of the expected yield increase on that soil minus the cost of the additional fertilizer, with inputs and outputs evaluated at current prices. The *average* expected new income for all producers is the weighted average of the expected new income for the various soils used in potato production. Let the yield response for soil i be represented by the quadratic response function

$$(1)\quad Y_i(X, Z_i, W) = [X' Z_i' W'] \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} + [X' Z_i' W'] \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} X \\ Z_i \\ W \end{bmatrix} + e$$

where $Y_i(X, Z_i, W)$ = potato yield in kilos per hectare on soil i,

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$X =$ a 3×1 vector representing applied nitrogen, phosphate, and potash in kilos per hectare,

$Z_i =$ a 4×1 vector of soil characteristics as measured by soil tests on soil *i;* organic matter measured in percent (as a proxy for soil nitrogen), soil phoshorus measured in *ppm,* soil potassium measured in *ppm,* and soil *pH,*

$W =$ a 2×1 vector of weather variables; millimeters of rainfall from October through March, mean of minimum daily temperatures in January and February (degrees centigrade),

$A =$ a 9×9 symmetric matrix of coefficients of quadratic and interaction terms,

$B =$ a 9×1 vector of coefficients of linear terms,

and $e =$ a random error term, distributed normally with mean zero and variance σ^2.

The expected returns net of fertilizer costs for soil *i* is

$$(2)\quad \Pi_i(X) = pY_i(X, Z_i, W) - P(1 + \delta)X$$

where $p =$ the price of potatoes in dollars per kilogram,

$P =$ a 1×3 vector representing prices of nitrogen, phosphate, and potassium, in dollars per kilogram,

and $\delta =$ interest charge for fetilizer expense (subject also to interpretation as a constraint on marginal rate of return).

The optimum levels of nitrogen, phosphorus, and potassium are obtained from equations (1) and (2) as

$$(3)\quad X_i{}^* = \frac{1 + \delta}{2P} A_{11}{}^{-1}P - (1/2)\, A_{11}{}^{-1}B_1 - A_{11}^{-1}\,[A_{12}\, A_{13}] \begin{bmatrix} Z_i \\ W \end{bmatrix}.$$

The value of δ may be interpreted alternatively as the interest rate or as a constraint on the marginal rate of return to money spent on fertilizer.[1] The expected new income obtainable by increasing fertilizer usage from some initial level X_i^0 to X_i^* for fixed prices can be represented as

$$(4)\quad R_i(X_i{}^0, X_i{}^*) = \pi_i(X_i{}^*) - \pi_i(X_i{}^0).$$

Finally, the *average* expected new income obtainable by all farmers under these circumstances is

$$(5)\quad \bar{R}(X^0, X^*) = \sum_i R_i(X_i{}^0, X_i{}^*) f(Z_i),$$

where $f(Z_i)$ is the relative frequency of occurrence of soil *i*.

Given the yield structure (1) and the marginal rate of return constraint δ, $\bar{R}(X^0, X^*)$ is the average new annual income which farmers could expect to receive in the short-run, if the parameters of the production function (1) were known. Smaller new income streams are available for alternative levels of X. Two such alternative levels will be considered in this study. The first consists of those levels of fertilizer currently recommended by the Soil Testing Laboratory in Peru and based largely on the same set of experimental data used in this study. The second consists of those levels of fertilizer which would be recommended for a soil with an average soil test, with these rates applied to all soils, regardless of soil test variables Z_i. Differences in these average annual incomes provide estimates of the value of soil testing and the value of direct estimation of (1) as opposed to the conventional approach to fertilizer recommendations utilized by the Soil Testing Laboratory in Peru.

Long-run consumers' income

In competitive industries the discovery of new information about use of inputs results in a downward shift of the supply curve, just as would the discovery of new material inputs. After equilibrium is restored, the social gain from the new information is the area between the old and new supply curves and under the demand curve. If it is assumed that the supply of inputs to potato production is perfectly elastic over the relevant range of use, then the impact of the new information is represented by Figure 1. Prior to the availability of the new information, the average firm is in equilibrium with output Y_0 under price P_0. The new information allows a shift in cost curves to MC_1 and ATC_1, with optimum output initially at Y_2 but dropping to Y_1 at the new equilibrium price P_1. The social gain from the new information is represented by the shaded area $(A + B)$, consisting entirely of additions to consumer surplus. This shaded area thus represents the size of the new consumer income made available once the market equilibration is achieved.

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[1] Minimum constraints on the marginal rate of return have been proposed as a more acceptable representation of producers' behavior under conditions of limited capital and/or risk and uncertainty. The constraint used here results in fertilizer being applied until the marginal rate of return per dollar spent on fertilizer is δ. Thus a value of zero for δ implies simple profit maximization.

Empirical Results

The preceding economic models provide a framework in which to evaluate the gains from new information regarding the use of fertilizer on potatoes in Peru. Potatoes are the principal crop of Peru, and from 1960 to the present many fertilizer response experiments have been conducted *on farms* throughout the Sierra. For the study reported here, use is made of data from a total of 90 experiments conducted at 65 different locations during 1964–1970. Experimental designs were generally of the central composite or factorial types, with four replications. For each site, soil test information was available, including percent organic matter (as a proxy for soil nitrogen), soil phosphorus, soil potassium, and soil *pH*. In addition to these variables, it was possible to obtain growing season rainfall and mean minimum daily temperature during the critical January–February period from weather stations in the general vicinity of each experiment.

Estimation of the generalized response function

Details of the regression procedures used to fit the quadratic function (1) may be found in Ryan and Perrin [8]. Table 1 lists the variables included in the response equation, and their estimated coefficients. It may be noted that equation (1) includes a total of 54 coefficients (since matrix A is symmetric, it includes only 45 unique coefficients), while only 33 coefficient estimates (plus an intercept term and a dummy variable) are shown in Table 1. The omitted coefficients were constrained to zero values prior to estimation on the basis of conversations with agronomists who indicated there was no biological reason to believe they might be significant.

Of the 35 coefficients estimated, 28 were of the anticipated sign and significantly different from zero at the 1 percent level. Five were significant but with unexpected signs. The signs of the coefficients for P_s and P_s^2 indicated increasing re-

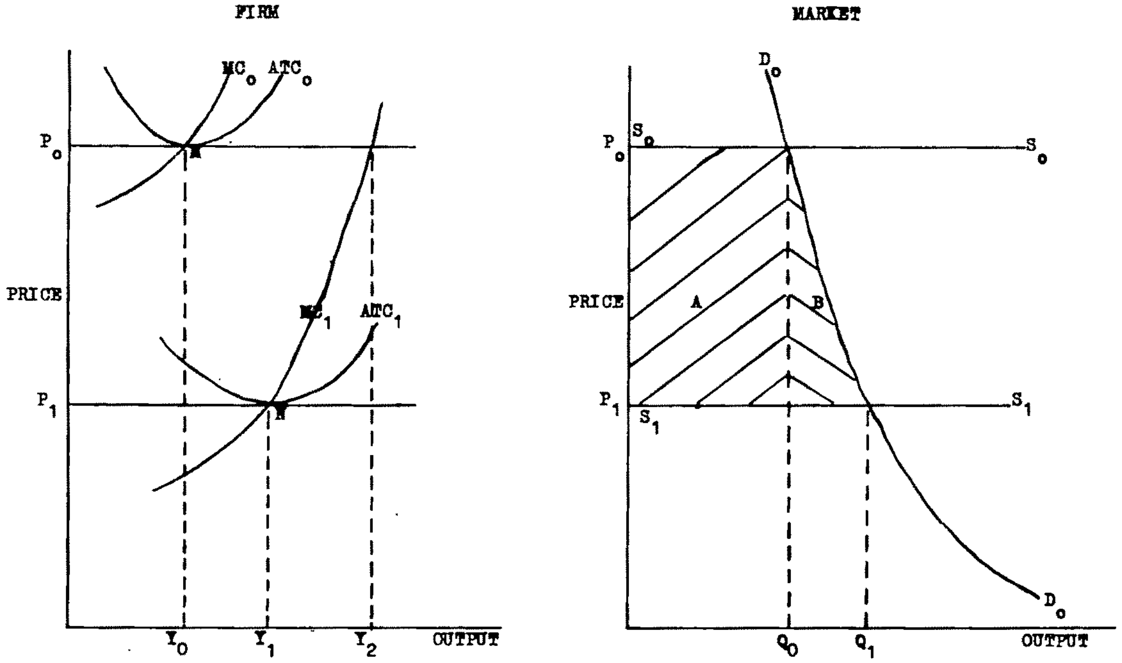

Figure 1. Effects of new information on the cost structure of the firm and on the product market

Table 1. Quadratic generalized production function for potato-fertilizer response, Sierra of Peru

Variable	Description	Units of measure	$\tilde{b}$ coefficient[a]	t'-value[b]
intercept		100 kg./ha.	—2084.2329*	—20.37
S	Magnesium deficiency	0 1	—217.3824*	—28.50
N_s	Organic matter	percent	84.7170*	11.32
P_s	Soil phosphorus	ppm	—3.3060*	—5.64
K_s	Soil potassium	ppm	0.7329*	23.83
pH	Soil pH	pH	136.7440*	12.24
N_a	Applied nitrogen	kg./ha.	0.1839	1.16
P_a	Applied phosphate	kg./ha.	1.1604*	7.72
K_a	Applied potash	kg./ha.	1.0122*	18.97
M	Rainfall	mm	1.0520*	9.77
T	Temperature	°C	347.3940*	17.88
N_s^2			—1.2800*	—8.80
P_s^2			0.1359*	10.84
K_s^2			—0.0006*	—14.03
pH^2			—10.2200*	—11.85
N_a^2			—0.0024*	—16.78
P_a^2			—0.0017*	—5.02
K_a^2			—0.0046*	—23.90
M^2			0.0003*	4.04
T^2			—16.6600*	—19.00
$N_s pH$			2.0910*	4.38
$N_s \cdot N_a$			0.0026	0.40
$N_s \cdot M$			—0.0529*	—11.33
$N_s \cdot T$			—7.7050*	—19.97
$P_s \cdot N_a$			—0.0112*	—5.25
$P_s \cdot P_a$			—0.0087*	—3.67
$K_s \cdot K_a$			—0.0017*	—10.90
$pH \cdot P_a$			—0.2289*	—15.29
$N_a \cdot P_a$			0.0017*	5.65
$N_a \cdot K_a$			0.0006*	2.86
$N_a \cdot M$			0.0004*	3.15
$N_a \cdot T$			0.0638*	6.07
$P_a \cdot K_a$			0.0009*	2.92
$P_a \cdot M$			0.0011*	9.25
$M \cdot T$			—0.1696*	—12.86

$R^2 = 0.43$

Coefficient of variation = 39.23

[a] * indicates significance at the 0.01 level, using a two-tailed test.

[b] These t-values were calculated using the formula $t' = \frac{t \cdot S_r}{S_a}$ where t is the ordinary t-statistic in the regression procedure, S_r the square-root of the residual error mean square from the regression, and S_a the square-root of block-in-location or pooled error mean squares from a combined analysis of variance of the data. The main effect of location (i.e., the terms involving only N_s, P_s, K_s, pH, M, and T) was tested using blocks-in-locations error while treatments (N_a, P_a, and K_a) and location by treatment interactions were tested against the pooled error.

turns to soil phosphorus, rather than decreasing as anticipated, and the sign for M^2 also indicated increasing returns to rainfall, which was not anticipated. The interaction terms for organic matter with weather ($N_s M$ and $N_s T$) were negative rather than positive as expected. In retrospect, however, soil scientists agreed that all five of these coefficients are consistent with existing theory.[2] The two insignificant coefficients were for the linear applied nitrogen term and for the interaction of applied nitrogen and soil organic matter. Insignificance of the former is not particularly disturbing, since the linear term becomes much larger in the absolute sense under average values of N_s,P_s and other variables which have interaction terms with nitrogen. The insignificance of the organic matter-nitrogen interaction term served to reinforce the belief by many agronomists that organic matter is not a good proxy for soil nitrogen.

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[2] While soils consultants generally expected diminishing returns to soil phosphorus and rainfall, they felt *ex post* that there was no reason to preclude the possibility of an increasing returns phase as suggested by the coefficients for P_s and M. Similarly, in retrospect they felt

Short-run increases in producers' income

The average new income which can be generated by this new information is determined by equation (5). To estimate this amount, an estimate of the frequency distribution of soils and the existing level of fertilizer use is needed in addition to the estimated response coefficients. At the time of this study (1972), specialists in Peru estimated that fertilizer use on potatoes in the Sierra averaged only six to ten kilograms per hectare, a negligible amount. To estimate the frequency distribution of soils, a sample of 1,541 soil analyses was obtained from the National Center of Soil Analysis in Peru. This sample was drawn from among all soils submitted from the Sierra for potato fertilization recommendations. Each analysis consisted of percent organic matter, parts per million of phosphorus and potassium, and soil *pH*. Estimating a joint frequency distribution function for these four variables was impractical, so the sample was classified into three ranges each for N_s and *pH*, and four ranges each for P_s and K_s, yielding 144 soil classes. The frequency distribution of the 1,541 soils over these 144 classes provided the $f(Z)$ function required for equation (5).

Assuming a marginal rate of return constraint of zero, the estimate of the annual income available by moving from no fertilizer use to optimum levels $[\bar{R}(0,X^*)]$ is $863 per hectare at current prices in Peru.[3] This of course does not represent the value of the *new* information contained in the response function, since conventional analyses have resulted in a set of recommendations which are currently being made (designated as $X\dagger$).[4] Again using equation (5), the average annual income available by moving from zero usage to levels currently recommended $[\bar{R}(0, X\dagger)]$ is calculated to be $663 per hectare.[5] By implication, then, the average *new* income which is made possible by the generalized production function analysis is $200 per hectare ($863–663) per year.

A related question is the value of soil test information itself. If soil tests were not made, producers are assumed here to rely upon a blanket recommendation for all soil types. If this blanket recommendation, denoted as X^+, is derived from equation (3) for average values of the soil variables, then the *average* value of the soil test information is given by $\bar{R}(X^+,X^*)$. For this sample of soils the *average* value of soil test information calculated in this manner was $94 per hectare. For those soils with analyses near the mean, soil testing would have little value since the assumption is that blanket recommendations would be derived for a soil with an average analysis. Among the 144 soils considered here, the value of the soil test ranged from about $1 to $430 per hectare.[6]

The above estimates of new income were derived under the assumption that producers would choose to maximize expected profits once they had full knowledge of the new information available. As suggested earlier, producers' behavior may be better characterized as maximizing expected profits subject to a constraint on marginal rate of return. Such a modification of maximizing behavior can be interpreted either as a result of risk aversion or as a result of capital constraints.[7] Given no *a priori* knowledge as to the level of such a constraint appropriate for Peruvian potato producers, calculations were made for mar-

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that it was quite possible that higher temperatures and rainfall could reduce, rather than increase, the marginal product of soil nitrogen in the Sierra, though they had anticipated otherwise.

[3] Average prices facing Sierra producers were reported to the authors by U. S. technicians in Peru as $0.048 per kilo of potatoes, and $0.219, $0.246, and $0.138 per kilo of N, P_2O_5, and K_2O applied as fertilizer, respectively.

[4] Current recommendations are also based on soil test results.

[5] This implies a very substantial disequilibrium in fertilizer use, in view of the fact that this response data has been available for a number of years. This point is discussed further in the last section.

[6] Bie and Ulph [1] and Colwell [3] have made similar analyses of the value of soil test information. Colwell's study included potato production in Ontario, for which the value of soil tests ranged from $6 to $120 per hectare, depending on soil test. The net returns from fertilizer in his study [corresponding to $R(0,X^*)$] ranged from $180 to $2,183 per hectare, figures which are quite consistent with those estimated in this study.

[7] Other models have been used to represent fertilizer use under risk, for example de Janvry [4] and Ryan and Perrin [8]. It is beyond the scope of this paper to discuss their implications with respect to the measurements attempted here.

Table 2. Effect of a marginal rate of return constraint on new income available from fertilizer use[a]

Constraint on MRR (δ)	Optimum fertilizer use[b]	New income (gross crop value minus fertilizer cost)
percent	kgs./ha.	$ per ha.
0	507	613
50	481	610
100	453	606
140	432	600
400	293	517

[a] Calculated from equation (4), using average weather and soil values: $M = 577$, $T = 6.78$, $N_s = 4.26$, $P_s = 10.78$, $K_s = 158$, and $pH = 6.65$.

[b] Total kilograms N, P_2O_5 and K_2O per hectare.

ginal rate of return constraints ranging from 50 percent to 400 percent. The new incomes available for an average soil, $R(0,X^*)$, under these circumstances are reported in Table 2. Constraints of 50 to 140 percent have very little effect on the amount of new income.[8] A constraint of 400 percent would imply that producers would choose to apply some 40 percent less fertilizer than profit-maximizing levels, resulting in a reduction in expected new income of $100 per hectare (roughly 16 percent). It is clear from this analysis that the hypothesis of behavior constrained by marginal rates of return can account for only a small fraction of the apparent disequilibrium in fertilizer use on potatoes in the Sierra.

Long-run consumers' income

The preceding analysis indicates that producers could increase their incomes by $863 per hectare by the adoption of profit-maximizing fertilizer rates as opposed to the negligible quantities now used. The theory of competitive industries, illustrated by Figure 1, suggests that this income stream will be passed on to consumers in the long run. To estimate the resulting social gain, areas $A + B$ in Figure 1, one must estimate the change in the firms' average total cost curve (the average total cost curve for one hectare) and the elasticity of demand for potatoes.

To estimate the firm-level cost curve, it is assumed that all factor supply curves facing the potato industry are perfectly elastic. Though potatoes are the primary crop of Peru, they utilize only about 10 percent of the arable land. The crop probably accounts for a larger proportion of other farm inputs, particularly in the Sierra. Even so, the assumption of perfectly elastic supplies of land and labor to potatoes in the *long run* is not unduly unrealistic. Since Peru is an importer of fertilizer, perfectly elastic supplies are quite plausible for this input also. Using budgets derived by Coffey [2, pp. 41–47], the current costs for land, labor, and materials other than fertilizer are estimated to be $365 per hectare. Given these fixed costs, it was determined that the minimum point on the new average total cost curve for an average soil occurs with the use of about 400 kilograms of fertilizer per hectare. The average total cost at that point is $.0166 per kilogram of potatoes, compared to the current price of about $.048 per kilo.

A study by Torres [9] indicates the elasticity of demand for potatoes to be about —0.3, while another estimate by Van de Wetering *et al.* is —.96 [10]. Using a recent estimate of total consumption (1.325 million metric tons in 1967), the former elasticity estimate yields an estimated annual increase in consumer welfare of $46 million annually, while the higher elasticity results in an estimate of $53 million annually.[9]

The above estimates of consumer income are based on adjustment to equilibrium assuming that producers would apply expected-profit maximizing levels of fertilizers. If producers' behavior is characterized by a marginal rate of return constraint, the previous analysis suggested that they might possibly apply as little as 293 kilos, which would result in an average total cost of $.0168 per kilo of potatoes, an increase of only $.0002 (1 percent) per kilo. While that analysis was made assuming a price of $.048 per kilo of potatoes, it suggests that adjustments for rate of return contraints would have little effect on the new equilibrium price of potatoes.

Given the inelasticity of demand for potatoes, market adjustments described above would reduce total revenue received by potato producers. However, if factor supply elasticities are indeed perfectly elastic in the long run, these factors have equally remunerative opportunities elsewhere and their owners would suffer no income losses. To the extent that short-run supply functions are not perfectly elastic, some factor owners would suffer short-run losses, however. Furthermore, if there were not a completely elastic supply of land and labor at existing prices, then prices of these factors would be bid down by substitution of fertilizer inputs for them. To the extent that this occurred, the new supply curve S_1S_1 would be lower. Measured net consumer gains would then be greater than the estimate of about $50 million annually. However, this overall gain would be at the expense of a redistribution of income away from potato farmers due to reduced factor rewards.

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[8] This reinforces a conclusion drawn by Doll [5] and by others that the elasticity of profits with respect to fertilizer use is quite small in the vicinity of profit-maximizing levels of fertilizer use.

[9] Griliches [6] has pointed out that estimates of social gain estimated in this fashion are in general not very sensitive to changes in price elasticity.

Conclusions

The purpose of the study reported here was to estimate the size of new income streams which can be generated by increased use of fertilizer on potatoes in Peru. It was found that current levels of use indicate a considerable disequilibrium in spite of the fact that response information and fertilizer recommendations have been available for a number of years. The estimated response function implies that potato producers would increase their incomes by an average of over $800 per hectare by adopting profit-maximizing levels of fertilizer. Market equilibrium resulting from the adoption of profit-maximizing levels would result in an estimated annual gain to consumers of about $50 million.

In view of the persistent apparent disequilibrium in fertilizer use, however, it must be concluded that these are at best upper bound estimates. This apparent disequilibrium is consistent with any of three hypotheses: (1) the estimated response function does not represent typical farm conditions (even though the trials were conducted on farmers' fields), and producers know it; (2) the response function is valid, but producers are ignorant; and (3) other factors inhibit the use of fertilizer. To the extent that the first hypothesis is correct, estimates based on the estimated response function will entail an error of unknown magnitude. If there is such an error, it is likely to be in the direction of overestimating response and therefore overestimating potential new income streams. However, the similarity of results to those of Colwell [3] offer some support for the validity of the empirical model. The second hypothesis implies that some expenditure on education would be required to achieve the estimated income gains, resulting in a reduction in net income gained. Little can be said about the implications of the third hypothesis, except that it implies that producers will apply less fertilizer than our model predicts. The study has shown that capital constraints are not likely to affect producer behavior to the extent of the apparent current disequilibrium. Other factors which might inhibit fertilizer use include imperfections in the fertilizer supply system, net producer prices which are greatly different from those used here, or risks perceived by producers and their reactions to these risks. Any of these factors might result in higher *de facto* production costs than have been estimated, thus reducing the income gains from the levels estimated.

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Estimation of Flexibility Coefficients for Recursive Programming Models—Alternative Approaches*

R. K. SAHI AND W. J. CRADDOCK

This paper presents a critical evaluation of some methods commonly used in estimating flexibility coefficients for recursive programming models. It also suggests an alternative procedure for estimating coefficients that vary from year to year depending upon economic and noneconomic conditions. This method was found empirically superior to some previous approaches.

Key words: **recursive programming; flexibility coefficient; agricultural production response; Canada.**

SEVERAL METHODS have been used in agricultural production response studies to estimate flexibility coefficients for recursive programming models[1] [3, 6, 13, 15]. In these studies, recursive programming has not been overly successful in the empirical estimation of supply response. The relatively poor performance of these models has been in part due to some major weaknesses in the estimation procedures for the flexibility coefficients. Bawden [1], Day [3], Doll [4], Miller [9], Schaller [12, 13], and others have recognized that the crux of recursive programming models lies in the estimation of the flexibility coefficients, and they have correspondingly recommended improvements in this direction. The purpose of this paper is to evaluate the theoretical underpinnings and empirical performance of four methods for estimating flexibility coefficients and to present an alternative approach.

Recursive Programming and Flexibility Restraints

Recursive programming may be described as an attempted synthesis of ordinary linear programming[2] and regression analysis of time series data. In terms of solution procedures, recursive programming and linear programming are similar. Both are employed to optimize a linear objective function subject to linear constraints. The difference between the models is of a conceptual nature. Recursive programming is capable of predicting the actual behavior of firms, whereas linear programming can only estimate an optimal behavior [6, pp. 242–43]. This characteristic of the recursive model is obtained through the use of flexibility constraints which are often estimated through a regression analysis of time-series observations.

Maximum and minimum flexibility restraints are utilized to represent upper and lower bounds on the allowable changes in the level of each enterprise in the programming solution from one time period to another [6, pp. 242–43]. Assuming an annual time period, these restraints relate the production pattern of one year with that of the preceding year and as such are based on the assumption that farmers' current year production decisions are deviations from the allocation pattern in the preceding year. A conglomeration of factors is responsible for farmers' inability or unwillingness to make large changes in an established production pattern. Some of these are risk and uncertainty associated with marketing and weather, insufficient knowledge, institutional restrictions, and personal preferences including goals other than short-run profit maximization [13, pp. 7–8]. Since these forces are usually not directly measurable, some indirect measurement needs to be employed. The use of flexibility restraints is such a method.

These restraints can be expressed mathematically as follows:

Upper flexibility restraints

$$(1) \qquad X_{it} \leqslant (1 + \bar{\beta}_{it}) \quad X_{it-1}$$

Lower flexibility restraints

$$(2) \qquad X_{it} \geqslant (1 - \underline{\beta}_{it}) \quad X_{it-1}$$

$$i = 1, \ldots, n$$

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[1] A definition of "recursive programming" is given below, along with a discussion of the role of flexibility coefficients.

[2] Hereafter referred to as "linear programming."

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where

X_{it} = level of the ith activity to be determined in t year,

X_{it-1} = level of the ith activity in $t-1$ year,

$\bar{\beta}_{it}, \underline{\beta}_{it}$ = maximum allowable proportionate increase and decrease, respectively, in the level of the ith activity from the $t-1$ year to the t year; these are known as upper and lower flexibility coefficients,

and

n = total number of activities.

The first equation indicates that the level of the activity in period t will not exceed the previous year's level plus some proportion of it as determined by the upper flexibility coefficient, $\bar{\beta}_{it}$. The second equation suggests that the current level of the activity must not be less than an amount determined by the lower flexibility coefficient, $\underline{\beta}_{it}$, and the preceding year's level. Thus, the level of the ith activity in the solution for t year is constrained within these limits.

Methods for Estimating Flexibility Coefficients

Previous methods

A number of methods have been proposed for estimating flexibility coefficients [13, pp. 8 and 66]. In summary form, some of these are:

(1) Calculate year-to-year proportionate change in the level of an enterprise in the past, and select maximum positive proportionate change as $\bar{\beta}$, and maximum negative proportionate change (ignoring sign) as $\underline{\beta}$,

(2) Determine the flexibility coefficient as the average of absolute proportionate changes which have occurred in the past and use the same average both as the upper and lower coefficients,

(3) Stratify year-to-year proportionate changes into two groups on the basis of direction of change, and then compute the average of positive changes to obtain upper flexibility coefficient and average of negative changes to estimate lower flexibility coefficient, and

(4) Determine upper and lower flexibility coefficients by estimating the following simple regression equations[3] using observations stratified into two groups on the basis of positive or negative year-to-year changes:

$$(3)\quad X_{it} = (1 + \bar{\beta}_i)X_{it-1} \qquad X_{it} > X_{it-1}$$

$$(4)\quad X_{it} = (1 - \underline{\beta}_1)X_{it-1} \qquad X_{it} \leqslant X_{it-1}.$$

All four of these methods estimate a pair of flexibility coefficients ($\bar{\beta}_i, \underline{\beta}_i$) which are used to calculate upper and lower flexibility restraints for each year. There are two major limitations of coefficients estimated in these ways. First, they are based on an unreasonable assumption that the maximum proportion by which farmers would like to increase (or decrease) the level of an enterprise is the *same* in all years regardless of the level of that enterprise in the preceding year. In actual practice, producers probably vary their production patterns at different rates in different years. Bawden [1, pp. 1549–1551] also criticized these coefficients for being independent of the production level of the previous year. Coefficient estimates based solely on proportional changes imply that the larger the base year acreage of one particular crop, the greater is the potential for absolute expansion. But in reality this situation is unlikely to happen due to a producer's desire for diversity, his reaction to the uncertainty attached to specialization, and limited total land. Generally, a farmer who devotes a higher proportion of one year's acreage to a given crop will increase the acreage proportionately less than a farmer who devotes a smaller proportion of his acreage to that crop [6, p. 244]. If this is the case, the flexibility coefficient should be estimated such that it varies with changes in the preceding year acreage.

Doll [4, p. 126] and King [8, pp. 1536–1538] have outlined a second limitation of the above methods for estimating flexibility coefficients. Since the coefficients do not vary from year to year in response to changes in economic and noneconomic conditions, they inadequately explain dynamic production response. In reality, the maximum rates by which farmers change production patterns from one year to the next vary, even though rates are based on factors such as personal preferences, risk, and uncertainty.

Glenn Johnson's criticism [7, pp. 25–28] of Nerlove's distributed lag model is also applicable to these methods of estimating flexibility coefficients. He states the following:

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[3] In order to avoid redundancy, two separate equations, one for $\bar{\beta}$ and another for $\underline{\beta}$, will not be presented hereafter. Rather, an equation will be specified for β (without upper and lower bars) because basically the same equation is applied in both cases. The difference is the application to two different data sets, one consisting of positive year-to-year changes in the level of an enterprise and the second of negative changes.

> Nerlove's coefficient of adjustment, γ, seems somewhat inadequate. A boy appears to have been sent to do a man's job. Do we really expect the difference between next year's production and this year's production to be some portion γ, where $0 < \gamma \leqslant 1$, of the difference between this year's 'long-run equilibrium output' and this year's actual output *regardless* of whether product prices have just reversed, have been going up for a number of years or have been going down for a number of years [italics ours]?

As flexibility coefficients are similar in concept to Nerlove's coefficient of adjustment [2, p. 110], they are amenable to the same criticisms.

This weakness of the above methods has also been revealed in several recursive programming studies. Schaller and Dean [13, p. 68] found that flexibility coefficients estimated in these ways were not adaptable to the conditions of each new year. The flexibility restraints in some years allowed too much flexibility in the solution and thereby caused overestimation of the crop acreages. In other years, the restraints were too narrow. Therefore, they recommended that the bounds should be estimated using more information than just the preceding year acreages. Richard Day [3, pp. 87–88] suggested that flexibility coefficients should be related to changes in prices and weather conditions.

In summary, flexibility coefficient estimates based on methods used in the previous studies would be immune to year-to-year changes in economic and noneconomic conditions. An alternative framework is developed below that allows the coefficients to vary from year to year depending upon the levels of exogenous variables.

An alternative method for estimated flexibility coefficients

It is assumed that there is a true flexibility coefficient for acreage of a crop,[4] β_t, upon which production decisions are made, but it is not observable. Instead, it is observed with error through the observable variable $(X_t/X_{t-1}) - 1$. This assumption can be stated in the following stochastic equation:

$$(5) \quad \frac{X_t}{X_{t-1}} = \beta'_t + \epsilon_t \quad \text{where} \quad \beta'_t = 1 + \beta_t,$$

and it is assumed $E\ (\epsilon_t) = 0$, $\mathrm{Var}\ (\epsilon_t) = \sigma^2$, and $\mathrm{Cov}\ (\beta_s, \epsilon_t) = 0$ for $s \leqslant t$.

Two hypotheses can be formulated regarding factors affecting flexibility coefficients. One is that the flexibility coefficient[5] for acreage of a crop depends upon the preceding year acreage of the crop in question. This hypothesis can be expressed as:

$$(6) \quad \beta'_{it} = \gamma_{io} + \gamma_{i1} X_{it-1} \qquad i = 1, \ldots, n.$$

Substitution of equation (6) into (5) results in

$$(7) \quad \frac{X_{it}}{X_{it-1}} = \gamma_{io} + \gamma_{i1} X_{it-1} + \epsilon_{it}.$$

If flexibility coefficients are estimated from equation (7), they would not be the same in each time period. Rather, they would vary depending upon the level of the preceding year's acreage. Since it is hypothesized that $\gamma_{i1} < 0$, a large flexibility coefficient would be estimated if the preceding year acreage of a crop was small. Likewise, a small flexibility coefficient would result if the base year acreage were large. In this study, equation (7) was estimated in a preliminary stage of the analysis, and the flexibility coefficients were used to compute flexibility restraints for the programming model. However, results based on these coefficients were inferior to those based on coefficients estimated from equation (10). Therefore, this method was not pursued further.

The second hypothesis is that the flexibility coefficient for acreage of a crop varies from year to year depending upon the expected levels of several exogenous variables. For example, the coefficient for a crop might depend upon the farmers' expected prices, inventories, and exports for the crop in question and its major competitor. Preceding year acreage and technological and weather conditions (e.g., precipitation) could be considered as other relevant explanatory variables. The relationship can be expressed as follows:

$$(8) \quad \beta'_{it} = f(X_{it-1}, P^*_{it}, P^*_{jt}, S^*_{it}, S^*_{jt}, E^*_{it}, E^*_{jt}, M_t, T_t) \qquad i = 1, \ldots, n$$

where

i = crop in question,

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[4] To avoid ambiguity in discussion, land allocation decisions have been used as the example in this paper.

[5] Hereafter, flexibility coefficient is referred to as β' $(= 1 + \beta)$ rather than β. Conceptually, it is immaterial whether the coefficient is defined as $1 + \beta$ or β because both have the same basic economic meaning. The differences are in the mathematical interpretation and the mechanics of computing flexibility restraints. In the case of $1 + \beta$, the flexibility restraint is the product of $1 + \beta$ and preceding year acreage, whereas in the case of β, 1 is added to it before multiplying with preceding year's acreage.

j = main competitive crop,

X_{it-1} = acreage of the ith crop in $t-1$ year,

P^*_{it}, P^*_{jt} = expected prices of the ith and jth crops, respectively, in t year,

S^*_{it}, S^*_{jt} = expected inventories for the ith and jth crops, respectively, in t year,

E^*_{it}, E^*_{jt} = expected exports for the ith and jth crops, respectively, in t year,

M_t = springtime moisture conditions,

and

T_t = time trend variable to account for technological change.

In order to transform the expected variables of equation (8) into observable variables, simple expectation models can be employed: the expected exports, prices, and inventories could be taken as the preceding year values. Because precipitation before seeding creates a gap between actual and intended land use, total rainfall during April and May could be treated as the relevant observation for the moisture variable.

After using the expectation models and assuming linear relationships between dependent and independent variables, equation (8) can be expressed as:

$$(9) \quad \beta'_{it} = \alpha_{0i} + \alpha_{1i}X_{it-1} + \alpha_{2i}P_{it-1} + \alpha_{3i}P_{jt-1} + \alpha_{4i}S_{it-1} + \alpha_{5i}S_{jt-1} + \alpha_{6i}E_{it-1} + \alpha_{7i}E_{jt-1} + \alpha_{8i}M_t + \alpha_{9i}T_t.$$

The variables of this function are not defined here because basically the same variables have been described in equation (8); a star indicates expected values and lack of a star represents actual values.

Substitution of equation (9) into (5) produces the following equation:[6]

$$(10) \quad \frac{X_{it}}{X_{it-1}} = \alpha_{0i} + \alpha_{1i}X_{it-1} + \alpha_{2i}P_{it-1} + \alpha_{3i}P_{jt-1} + \alpha_{4i}S_{it-1} + \alpha_{5i}S_{jt-1} + \alpha_{6i}E_{it-1} + \alpha_{7i}E_{jt-1} + \alpha_{8i}M_t + \alpha_{9i}T_t + \epsilon_{it}.$$

Equation (10) shows that sources of year-to-year variations in flexibility coefficients are changes in the base year acreage and variations in the levels of other exogenous variables. Since the coefficient estimates from the above method vary in response to changes in the explanatory variables, this method can be applied to estimate the effects of some policy changes on land use. However, in the event of major structural change, the adequacy of this method is greatly reduced because it is based on historical time-series data. Farm surveys could be employed to estimate the coefficients in this situation.

Due to insufficient degrees of freedom, it was possible to include only a few variables in each regression equation. The selection of variables was influenced by: (1) multicollinearity between independent variables; (2) inconsistent signs of coefficients with *a priori* expectations; (3) the "t" values of the coefficients; and (4) the R^2. In some equations, it became necessary to transform price variables in such a way that price ratios were used in the place of individual prices.

Analytical Models for Canadian Prairie Land Utilization Patterns

Constraints

In order to compare the empirical performance of the method developed in this study with some of the approaches used in previous studies,[7] three recursive programming models for prairie land utilization patterns were developed. These models were identical in every respect, except in the estimation of the flexibility restraints. The three methods used to estimate flexibility coefficients are:

(1) The maximum of positive proportionate changes which occurred during 1953 to 1967 was selected as $\overline{\beta}$, and the maximum negative proportionate change (ignoring sign) was treated as $\underline{\beta}$. The programming model based on this method is referred to as Model M-1.

(2) Simple regression equations such as (3) and (4) were utilized to estimate coefficients. The

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[6] Inclusion of X_{it-1} on both sides of the equation clearly violates the assumption for least-square estimators that disturbance term and explanatory variables should be independent. Under this situation least-square estimators are biased [5, pp. 273–77]. Using an alternative specification, this problem might be overcome. However, other problems could arise. For example, by multiplying X_{it-1} to both sides of equation (10), we will eliminate the variable from the left side of the equation, but a very serious case of multicollinearity results. The second limitation of this formulation is that the estimates of flexibility coefficients cannot be obtained directly; rather, some further calculations are necessary. For computational simplicity, therefore, equation (10) was used.

[7] Only two of the four "Previous Methods" discussed above were selected to estimate flexibility coefficients. Methods 2 and 3 were not used because their estimates are likely to be inferior or equal to those of method 4.

programming model using these flexibility coefficients is designated as Model M-2.

(3) The method developed in this study [equation (10)] was utilized to estimate coefficients and to construct Model M-3.

For estimating upper and lower flexibility coefficients separately, observations over the period 1953 through 1967 were stratified into two groups on the basis of positive or negative changes in year-to-year acreages of a crop. All three methods were then used to estimate upper flexibility coefficient for each crop using positive changes in year-to-year acreages. Likewise, the lower coefficient for each crop was estimated using negative changes in crop acreages. *Ex ante* flexibility coefficients for 1968 and 1969 were estimated in a similar way. The coefficients were used to compute flexibility restraints for each crop.

Only two physical resource restraints were included in the model—the total arable acreage for the current year and the summerfallow acreage of the preceding year. Grain marketing quota restraints were used in the model since quotas influence farmers' production decisions by affecting the marginal return of using land for one crop relative to other crops (cf. [10] for greater detail).

Activities

The six major crops of the prairies were included in this study. These crops are: wheat, oats, barley, rye, flax, and rapeseed. In addition, summerfallow was included in the model as an activity. Two producing activities were employed for each crop, one for crops seeded on summerfallow and one for crops grown on stubble. To account for Canadian Wheat Board restrictions on sales of crops, selling alternatives were included for each crop.

Table 1. Turning point errors in estimates of the crop acreages in the prairies, 1958 to 1967

Crops	Total Number of Turning Points in Each Model	Number of Turning Point Errors		
		Model M-1	Model M-2	Model M-3
Wheat	10	2	2	2
Oats	10	4	4	5
Barley	10	4	5	2
Rye	10	7	7	1
Flaxseed	10	5	6	4
Rapeseed	10	3	3	1
Summerfallow	10	5	5	2
Total	70	30	32	17

Results

To determine the relative performance of the three methods of estimating flexibility coefficients, all three recursive programming models were solved for each individual year from 1958 through 1967. Estimates of the models were compared with actual crop acreages treated as a norm to determine their relative ability to explain land utilization patterns. Each model was also utilized to predict acreages for 1968 and 1969. These estimates were then compared with the actual acreages to evaluate the predictive ability of the models.

The explanatory test

The relative accuracy of alternative models in explaining prairie land utilization patterns was judged on the basis of three criteria:

(1) Direction of change in crop acreages (turning points),

(2) Theil's inequality coefficient,[8] U, and

(3) The weighted average of absolute percent deviations between actual and estimated acreages.

Based on all three criteria, the prairie land use was explained more adequately by Model M-3 than Model M-1 or M-2 during the period 1958 through 1967. The number of turning point errors for each crop except oats was the smallest with Model M-3 (Table 1). For all land use, Model M-3 had half as many turning errors as Model M-1 or M-2.

Theil's inequality coefficient, U, for entire land use during 1958 to 1967 was .054 for Model M-1, .029 for Model M-2, and .019 for Model M-3 (Table 2). The weighted average of absolute deviations was 12.03 percent for Model M-1, 6.52 percent for M-2, and 3.76 percent for M-3. On an individual year basis, Model M-3 had smaller errors than Models M-1 and M-2 in each year. For five years out of 10, the errors for Model M-3 were about half the size of the errors

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[8] The coefficient was estimated using the following formula:

$$U = \frac{\sqrt{\frac{1}{n}\Sigma\,(P_i - A_i)^2}}{\sqrt{\frac{1}{n}\Sigma\,P_i^2} + \sqrt{\frac{1}{n}\Sigma\,A_i^2}}$$

where A_i is actual acreage, P_i is predicted acreage, and n is the number of observations. The coefficient U varies between zero and unity; zero indicates complete semblance between estimated and actual values, and unity reflects a negative proportionality [14, pp. 31–42].

Table 2. Deviations of estimated from actual prairie crop acreages for three selected models, 1958–1967[a]

	Wheat			Oats			Barley			Rye			Flaxseed		
Year	M-1	M-2	M-3	M-1	M-2	M-3	M-1	M-2	M-3	M-1	M-2	M-3	M-1	M-2	M-3
								percent							
1958	—8.39	—1.49	—3.13	26.51	15.16	14.94	18.87	—4.76	—1.00	48.96	26.91	.46	—121.62	—72.29	—37.05
1959	.08	6.45	4.26	21.72	—5.19	1.44	5.18	—4.40	—4.86	54.59	34.93	3.93	—107.35	—56.71	—35.34
1960	—11.82	—4.71	—2.67	26.32	3.91	9.27	7.56	—1.78	—.42	54.90	35.31	.41	—35.79	—2.66	—2.98
1961	—8.20	—1.31	—.65	5.47	—11.62	—31.08	.07	—10.02	2.91	51.93	31.24	5.88	35.88	9.17	15.36
1962	—4.67	2.00	—.52	45.72	37.33	14.92	—33.88	—20.11	—9.16	57.19	38.67	7.37	22.13	—59.38	—29.87
1963	—8.36	—1.46	—.97	13.40	.03	.94	1.76	4.98	4.36	54.03	33.96	1.20	54.57	35.67	14.97
1964	—3.51	3.08	1.06	6.11	—8.39	1.11	—13.92	—24.06	—14.45	54.52	35.00	2.58	54.96	36.17	37.16
1965	—16.68	—9.25	—6.07	32.13	21.67	13.59	—11.81	11.43	5.43	56.73	37.92	1.74	55.14	36.47	35.28
1966	—3.37	.52	.09	21.49	9.38	—4.15	34.32	14.24	11.84	50.22	28.76	1.34	36.27	9.67	3.45
1967	—.22	—1.75	1.78	18.84	6.31	—10.96	26.03	18.55	2.28	48.41	26.11	—2.23	0.00	—41.68	—13.03
Wt. Av. of Abs. Per. Devs.[b]	6.41	3.18	1.99	22.72	12.45	10.19	15.66	10.13	5.26	53.19	32.95	2.67	57.66	35.24	22.99
Theil's *U*	.039	.021	.013	.150	.092	.066	.102	.057	.032	.363	.199	.017	.305	.197	.133

	Rapeseed			Summerfallow			Wt. Av. of Abs. Per. Devs.[b]			Theil's *U*		
Year	M-1	M-2	M-3	M-1	M-2	M-3	M-1	M-2	M-3	M-1	M-2	M-3
						percent						
1958	—254.15	—77.64	—100.00	11.35	7.83	5.52	19.48	9.24	7.01	.077	.042	.030
1959	—788.73	—428.17	—212.21	7.39	3.71	1.59	11.58	8.09	4.63	.050	.033	.020
1960	0.00	49.80	—6.29	4.72	1.89	.74	11.00	3.88	2.34	.049	.018	.012
1961	—284.93	—93.10	—7.46	9.94	6.37	4.69	12.21	6.39	5.45	.054	.028	.028
1962	—253.10	—243.94	—25.61	—.03	—2.36	.03	11.41	9.98	3.26	.051	.041	.016
1963	—178.03	—39.54	—11.92	.86	—1.81	—.91	7.95	3.12	1.64	.034	.012	.006
1964	—116.43	—8.60	15.68	3.74	—.22	—1.75	7.75	5.23	3.52	.027	.022	.015
1965	—97.42	.98	—1.53	.96	—1.55	—.68	14.85	8.50	5.39	.066	.038	.026
1966	—237.05	—69.11	—6.23	.00	—3.96	—2.45	13.04	5.78	2.64	.059	.023	.013
1967	—237.16	—69.14	5.86	3.34	.61	.32	11.22	5.75	2.21	.056	.024	.010
Wt. Av. of Abs. Per. Devs.[b]	197.61	67.85	19.54	4.26	3.04	1.87	12.03	6.52	3.76			
Theil's *U*	.520	.278	.125	.030	.019	.013				.054	.029	.019

[a] A positive deviation indicates an underestimate (i.e., estimated acreage less than actual), and a negative error represents an overestimate.

[b] Weighted average of absolute percent deviations.

of Model M-2 and less than one-third of the errors of Model M-1.

For each crop, Model M-3 was superior, on average, to Models M-1 and M-2 in explaining the 1958 to 1967 acreages. Model M-3 estimated rye acreages more closely than Models M-1 and M-2 for all years and estimated acreages of all other crops, except oats, more closely for eight years out of 10.

A crop-wise comparison of errors estimated by Model M-3 reveals that acreages of wheat, barley, and rye were estimated better (in percentage terms) than acreages of flax and rapeseed. The reason was that year-to-year fluctuations in acreages of the latter crops were much sharper (in percentage terms) than in acreages of the former crops.

The predictive test

This test is more rigorous than the explanatory one because the ability of the model to predict *outside* the period used for its construction is examined, and permanence and completeness of the structure are thereby evaluated. The models which were developed on the basis of the 1958 through 1967 data were used to make predictions for 1968 and 1969. Comparisons were then made among estimates of all models again treating actual acreage as a norm.

The Model M-3 predicted prairie land use more closely than Models M-1 and M-2 (Table 3). The coefficient *U* averaged over 1968 and 1969 was .078 for Model M-1, .065 for Model M-2, and .041 for M-3. The weighted averages of the absolute deviations for the same years were 18.88 percent for Model M-1, 13.15 percent for Model M-2, and 7.24 percent for M-3. In each year, Model M-2 predicted acreages more accurately than Model M-1, but less accurately than Model M-3.

A crop-wise comparison indicates that Model M-3 predicted acreages of all crops except flax more accurately than Models M-1 and M-2. Thus it can be concluded that among the models considered, Model M-3 performed the best and M-2 predicted acreages better than M-1.

Table 3. Deviations of predicted from actual prairie crop acreages for three selected models, 1968–1969[a]

	1968			1969			Wt. Av. of Abs. Per. Devs.[b]			Theil's *U*		
Crops	M-1	M-2	M-3	M-1	M-2	M-3	M-1	M-2	M-3	M-1	M-2	M-3
						percent						
Wheat	—9.43	—6.97	—1.69	—9.52	—23.48	—15.90	9.47	14.53	8.66	.045	.075	.053
Oats	27.75	10.56	4.36	28.10	15.56	—11.28	27.93	13.13	7.91	.162	.072	.043
Barley	26.83	19.44	1.62	25.77	—5.70	4.51	26.28	12.30	3.12	.151	.071	.018
Rye	51.05	29.73	—5.33	65.19	50.17	23.98	59.27	41.61	16.17	.433	.281	.105
Flaxseed	64.78	17.50	10.46	—3.22	21.98	39.71	185.15	20.25	28.43	.603	.146	.201
Rapeseed	—451.62	—176.71	—53.99	—87.28	6.06	29.22	212.37	64.65	37.73	.551	.324	.185
Summerfallow	9.19	5.58	2.11	13.63	10.21	4.96	11.49	7.98	3.59	.063	.044	.020
Wt. Av. of Abs. Per. Devs.[b]	20.63	11.04	3.01	17.16	15.24	11.42	18.88	13.15	7.24			
Theil's *U*	.083	.044	.012	.074	.081	.057				.078	.065	.041

[a] A positive deviation indicates an underestimate (i.e., predicted acreage less than actual), and a negative error represents an overestimate.

[b] Weighted average of absolute percent deviations.

Summary

In previous recursive programming studies, several methods were used to compute flexibility coefficients. The coefficients were estimated such that they were immune to year-to-year changes in economic and noneconomic variables. In reality, the maximum rates by which farmers are likely to increase (or decrease) the level of an enterprise vary from year to year in response to changes in these variables.

In this study, an alternative approach for estimating flexibility coefficients was developed. The coefficients were estimated so that they were dependent upon the levels of economic and noneconomic forces prevailing in that year. The performance of the new approach was compared with two methods selected from the previous studies. The recursive programming model based on the new method explained the 1958 to 1969 changes in prairie crop acreages with substantially more accuracy than models based on previous methods for estimating flexibility coefficients. It is therefore concluded that the new method is superior to methods previously utilized.

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PROCEEDINGS PAPERS

WINTER MEETING OF THE AMERICAN AGRICULTURAL ECONOMICS
ASSOCIATION WITH ALLIED SOCIAL SCIENCE ASSOCIATIONS

New York, December 27–30, 1973

U. S. POLICIES FOR FOOD, AGRICULTURE AND TRADE

CHAIRMAN: KENNETH R. FARRELL, U. S. DEPARTMENT OF AGRICULTURE

The World Food Situation in Perspective

DON PAARLBERG

MY TASK TODAY is to set the stage for a discussion of U. S. policies and policy alternatives for food, agriculture, and trade. I shall attempt to describe the past and present and to establish a perspective from which to view the likely future world food situation. My analysis will attempt to separate the short-lived events that so often draw the greatest public attention from the persistent underlying trends that will shape world agriculture of the future. This is no easy job. What is an aberration to one man is the beginning of a new trend to another. I shall conclude by listing some of what I believe to be the most important questions and issues suggested by the analysis.

In reacting to production shortfalls throughout the world in 1972, we tended to lose sight of the fact that there has been much stability in the trends for food production over the past two decades. World food production per capita trended upward during the 1954–72 period, with an annual increase of about ¾ of 1 percent (Table 1). The drop in 1972 was the largest during this entire period. Total food production increased at about the same rate in both the developed and developing world, but the very rapid pace of population growth in the less developed regions cut the per capita increase in production to less than ½ of 1 percent annually while the developed regions enjoyed an annual per capita increase of about 1½ percent.

We cannot, of course, conclude from these indices that there has been an equivalent lifting in nutrition levels everywhere or a reduction in the number of hungry people or improvement in other measures of human welfare. Still, our data indicate the world's growing potential for improving diets around the globe.

Cereals comprise the most important food staple group among the high carbohydrate foods upon which most of the world's population relies for a major share of its diet. Cereals are also the major protein source, although a somewhat less important source in areas where animal products are relatively plentiful. In less developed areas, dependence on cereals for protein is especially important. But they are more than foodstuffs. According to FAO food balances for 1964–66, 48 percent of cereals produced outside Communist Asia were used for food, 38 percent for animal feed, and 14 percent for seed, starch, liquor, and other uses. We can expect the total *direct* food use of cereals to rise in the future as poulation grows, but use of cereal food will decline in importance to other foods as incomes rise.

When we look at the total production of grain over the last two decades, we see a great difference in the performance of the developed and less developed regions. In the developed countries grain production increased more than 60 percent while planted area was nearly unchanged at something under 300 million hectares—all the increase was from higher yields. Grain production of less developed countries increased even more, almost 75 percent, but it required a ⅓ increase in area since yields were increasing only about ½ as fast as in the developed regions. While the area planted to grains in both the developed and developing countries is now about equal, average grain yields in the developing countries are now only about 60 percent of those in the developed countries. Another way to look at it is that average yields in the less developed countries now equal those recorded for the developed countries in the early 1950's.

Have recent events signaled a fundamental deterioration in the world food situation? Unusually poor weather in 1972 contributed to severe

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Table 1. World agricultural production, 1963–72 (1961–65 = 100)

Year	Total Agricultural Production			Agricultural Production Per Capita		
	World[a]	Developed Countries[b]	Less-Developed Countries[c]	World[a]	Developed Countries[b]	Less-Developed Countries[c]
1963	100	99	101	100	99	101
1964	103	104	103	101	103	101
1965	104	104	104	100	102	99
1966	108	110	105	102	106	97
1967	112	113	110	104	108	100
1968	116	117	114	105	111	101
1969	117	116	119	104	109	102
1970	120	118	123	105	110	103
1971	124	123	126	107	113	103
1972	123	123	124	104	112	99
1973[d]	130	129	131	108	117	102

[a] Excludes Communist Asia.
[b] North America, Europe, USSR, Japan, Republic of South Africa, Australia, and New Zealand.
[c] Latin America, Asia (except Japan and Communist Asia), and Africa (except Republic of South Africa).
[d] Preliminary.

production shortfalls in the Soviet Union, India, Southeast Asia, Australia, and many other areas. The Soviet Union decided to import massive quantities of grain to maintain livestock production. China entered the U. S. market. Stocks were drawn down. Prices rose. Population growth continued unabated. Those who doubt the world's ability to feed its people can cite this persuasive evidence.

But as 1973 draws to a close, prospects are for record world grain and oilseed crops. Supplies of grain and oilseed meal should be adequate to allow both total and per capita consumption to increase, although possible decisions of importing nations to stockpile supplies could cut into consumption for the 1973–74 marketing year. Rice supplies are the tightest among major commodities and will remain so even after grain from the Asian rice harvest now being completed reaches the market (Table 2). Wheat supplies (Table 3) are not quite so tight while coarse grains (Table 4) have the most breathing room. But even with these production advances, stocks of food and feed grains in exporting countries may still be slightly below last year's level when the 1973–74 marketing year ends next June 30th. The combination of thin stocks, increasing populations, the push towards improved diets, and the desire by importing countries to rebuild stocks should keep supplies tight at least for awhile. Worldwide inflation and the devaluation of the dollar have probably carried prices of United States farm products permanently above the levels of the sixties.

We expect that present high prices will call forth further increases in output by producers around the world. Grain farmers in the United States and Canada are being encouraged to produce more grain, backed up by measures such as the removal of all U. S. acreage restrictions. Purchases are increasing for irrigation facilities, machinery, and improved seed. Thus, in the 1974–75 marketing year, if weather conditions are normal or better, there should be a rebuilding of grain stocks throughout the world and a resulting decline of prices from the extraordinary levels reached in 1973.

In the years immediately ahead, I see neither an era of insatiable demand and rocketing prices for food nor a return to low prices and the generation of huge surpluses in the major grain exporting countries. I think a third situation is more likely than either of these two. I think we may see a recovery of agricultural production in the world and a per capita supply of food resuming its upward trend. But it is unlikely that prices of farm products will fall to the levels that prevailed two years ago.

What are the factors which could upset this forecast? Weather obviously leads the list. If, in 1974, there should be a repetition of 1972's poor weather conditions throughout the world, we would be in a very serious situation. But so far we have seen no conclusively convincing work by meteorologists which would permit us to assume anything other than normal weather in our forecast.

The availability of a sufficient supply of production inputs—particularly fuels and fertilizers—is of major concern. The world situation for

Table 2. Milled rice: production, consumption, and trade in 1970 and projected to 1985 (preliminary)

Region or Country	1970 Base[a] Production	1970 Base[a] Consumption	1970 Base[a] Net Exports	1985 Alternative I Production	1985 Alternative I Consumption	1985 Alternative I Net exports
			Thousand metric tons			
United States	2,852	1,176	1,733	3,793	1,441	2,352
Canada	—	50	—50	—	68	—68
Japan	11,399	11,862	561	10,780	10,880	—100
European Community	600	785	—11	549	889	—399
Other West Europe	433	493	—60	524	531	—7
Eastern Europe	115	346	—231	164	473	—309
Soviet Union	827	1,127	—300	2,274	2,553	—279
China	64,883	64,048	785	82,236	81,484	752
Argentina	218	136	82	374	225	149
Australia & N.Z.	187	37	150	383	147	236
Subtotal	81,514	80,060	2,659	101,077	98,691	2,327
Other regions						
Developed	10	82	—72	5	178	—173
Less developed	118,104	120,011	—1,905	178,542	180,472	—1,930
Subtotal	118,114	120,093	—1,977	178,547	180,650	—2,103
World total	199,628	200,153	682	279,624	279,341	224

[a] Average of 1969/70–1971/72. Production primarily in initial calendar year is combined with trade in following calendar year to obtain consumption. Some regions do not balance because of change in stocks.

Table 3. Wheat: production, consumption, and trade in 1970 and projected to 1985 (preliminary)

Region or Country	1970 Base[a] Production	1970 Base[a] Consumption	1970 Base[a] Net exports[b]	1970 Base[a] Exports	1970 Base[a] Imports	1985 Alternative I (Conservative) Production	1985 Alternative I (Conservative) Consumption	1985 Alternative I (Conservative) Net exports	1985 Alternative I (Conservative) Exports	1985 Alternative I (Conservative) Imports
					Million metric tons					
United States	40.2	22.7	18.0	18.0	neg.	49.7	28.7	21.1	21.2	0.1
Canada	14.0	4.6	11.4	11.4	neg.	19.9	4.4	15.5	15.6	.1
Japan	.6	5.3	—4.7	0	4.7	.3	7.3	—7.0	0	7.0
European Community	36.8	40.3	—3.2	8.3	11.5	45.3	45.3	0	5.0	5.0
Other West Europe	9.8	10.6	—0.8	.6	1.4	10.7	10.9	—0.2	1.3	1.5
Eastern Europe	26.1	31.2	—5.1	.3	5.4	37.4	36.3	1.1	2.0	0.9
Soviet Union	92.8	88.2	4.6	6.2	1.6	115.0	115.0	0	3.0	3.0
China	23.8	27.7	—3.9	0	3.9	35.5	40.5	—5.0	0	5.0
Argentina	5.7	4.2	1.4	1.7	0.2	8.5	5.0	3.5	3.5	0
Australia & N.Z.	9.4	2.8	8.4	8.5	neg.	12.5	3.8	8.7	8.7	0
Subtotal	259.2	237.6	26.2	55.0	28.7	334.8	297.2	37.7	60.3	22.6
Other regions										
Developed	1.4	1.5	—0.1	—	.1	2.2	2.2	0		
Less Developed	57.3	78.5	—23.3	.2	22.6	94.0	131.7	—37.7		
Subtotal	58.7	80.0	—23.4	.2	22.7	96.2	133.9	—37.7		
World Total	317.9	317.6	2.8	55.2	51.4	431.0	431.1	0		

[a] 3-year average centered on 1970.

[b] May not balance because of stocks.

Table 4. Coarse grains: production, consumption, and trade in 1970 and projected to 1985 (preliminary)

						1985					
	1970 Base[a]					Alternative I (Conservative)					Alternative II (Dynamic)
Region or Country	Production	Consumption	Net[b] exports	Exports	Imports	Production	Consumption	Net exports	Exports	Imports	Net exports
						Million metric tons					
United States	163.9	143.7	20.5	20.9	0.4	232.5	202.3	30.2	30.7	0.5	56.3
Canada	20.5	17.3	3.0	3.4	.4	26.1	21.6	4.5	5.0	.5	5.5
Japan	.7	11.0	—10.2	0	10.2	.4	28.4	—28.0	0	28.0	—30.0
European Community	56.4	68.5	—12.8	9.4	22.2	87.7	89.0	—1.3	1.0	2.3	—8.0
Other West Europe	18.6	22.5	—3.9	.8	4.6	26.6	32.6	—6.0	.8	6.8	—6.5
Eastern Europe	48.3	50.4	—2.1	1.0	3.1	65.3	67.3	—2.0	1.0	3.0	—6.0
Soviet Union	75.2	76.6	—1.4	.1	1.6	110.0	110.0	0	0	0	—8.0
China	71.0	71.0	0	0	0	92.0	92.0	0	0	0	—1.0
Argentina	13.4	6.8	6.6	6.6	0	16.7	7.7	9.0	9.0	0	10.0
Australia & N.Z.	5.3	3.0	2.1	2.1	neg.	9.8	4.6	5.2	5.2	0	6.0
Subtotal	473.3	470.8	1.8	44.3	42.5	667.1	665.5	11.6	52.7	41.1	18.3
Other regions											
Developed	9.0	7.7	1.3	1.3	neg.	12.7	8.4	4.3	4.3	neg.	4.5
Less Developed	110.1	111.4	—.7	4.2	4.8	161.9	177.8	—15.9			—22.8
Subtotal	119.1	119.1	.6	5.5	4.8	174.6	186.2	—11.6			—18.3
World Total	592.4	589.9	2.4	49.8	47.3	841.7	841.7	0			0

[a] 3-year average centered on 1970.

[b] May not balance because of stocks.

nitrogenous and phosphatic fertilizers is tight although supplies of potash seem adequate. The problem for nitrogenous fertilizers is complicated by a shortage of natural gas, a raw material used frequently in the production process. There were dire predictions of insufficient fuel to carry out this autumn's harvest in the United States, but somehow farmers in general received enough fuel and produced record grain and oilseed crops. It is reasonable to believe that governments throughout the world will attach sufficient importance to insuring an adequate food supply so as to give agriculture a high priority in the competition for scarce resources.

In concluding this discussion of the recent past and near-term future, I do not want to leave the impression that good prospects for achieving continued growth of per capita food consumption throughout the world mean that no problems remain. For instance, I fully recognize that when grain stocks are low, as now, the resulting high prices affect nations and individuals differently. It is the poor, both in the developed and developing nations, who are hit hardest by high prices. Low-income nations find it more difficult to obtain food aid, and they face the necessity of using additional scarce foreign exchange resources to meet higher commercial prices for food—resources which they would prefer to spend on long-term development programs, perhaps in agriculture itself. Such questions deserve more attention than time permits us to give them here.

If there is a universal complaint by social scientists about those in government, it is that we spend too much time reacting to day-to-day crises and not enough time considering the possible shape of the longer-term future. There is a lot to that complaint: I've made it myself, both in my classroom at Purdue and in my second-floor office in the USDA Administration Building. So I am especially pleased to have the opportunity today of discussing with you some of the work done in our Economic Research Service which attempts simultaneously to project demand, production, and trade for grains to 1985. Inputs to this analysis were growth rates for population and income, demand and supply price elasticities, and assumed policy constraints. Other trends taken into account included changes in tastes and preferences in consumption, such as the increasing desire for livestock products as peoples' incomes rise, and changes in resource constraints. Anticipated changes in yield were worked into the analysis. Normal weather was assumed (i.e., average conditions which cancel out both unusually poor or good years).

Specifically, we assumed the following: The medium growth variant of the U. N. population projections; continuing rapid growth of the world economy; world price levels inflating at the rate experienced in the recent decade; recent developments in production trends which capture the effect so far of the "green revolution"; and an essential continuity in present policies guiding domestic production, consumption, and international trade. We term these our *Alternative I*, a conservative projection.

Projections under *Alternative I* suggest that the world's capacity for production of cereals will increase faster than consumption and that there will likely be a rebuilding of grain stocks, downward pressures on prices, or possibly programs to restrict production in the major exporting countries, or some combination of these. Consumption and trade of wheat and rice should grow less rapidly than coarse grains because of the growing need for feed for livestock and poultry.

These projections also suggest that countries in the developed and in the centrally-planned parts of the world will continue to be the major producers and consumers of wheat and coarse grains. The developed countries will continue to supply the less developed countries (LDC's) with grain. The latter will import more wheat, while developed countries will increase their feed grain imports. This is because the limited foreign exchange of LDC's will cause them to give food grains priority over feed grains. Projected production and trade of the LDC's should permit per capita consumption of grains to increase slightly over the base period. But any larger increase will most likely have to come from greater domestic production than from larger imports. Korea and Taiwan, however, are examples of areas where wheat is not grown and where significant growth in imports of wheat is projected.

The enlarged European Community would be expected to approach self-sufficiency in grains as would Eastern Europe and the USSR, even though right now they are substantial importers of feed grains. China would likely import wheat and export rice. Japan would remain the largest single import market for wheat and coarse grains.

But what if world demand for grains should grow more rapidly than anticipated under Alternative I? We developed Alternative II, which embraces a more dynamic set of changes. Our *Alternative II* projections attempt to incorporate the following additional assumptions:

—The USSR and Eastern Europe attempt to increase livestock production and consumption at a faster rate of growth even if it means importing grain and high overall levels of trade with the western world;

—The People's Republic of China becomes more trade oriented and imports more grain to improve city diets;

—The enlarged European Community finds it advantageous to set lower price targets with a liberalizing effect on import restrictions;

—The livestock economies, particularly poultry, of the developing world grow faster, either in countries with enhanced petroleum revenues, or in countries with unexpectedly higher rates of economic growth;

—And fishmeal production stagnates at the 1969–71 level.

With the greater dynamism of *Alternative II*, the higher demand for livestock products should essentially translate into a substantial increase in demand for coarse grains with relatively little impact on the demand for wheat or rice, although one would expect higher feed prices to encourage more feeding of wheat in the developed countries. Our projections show the United States meeting nearly all of the increased demand, with U. S. exports of feed grains reaching 56 million metric tons, or about 25 million tons higher than under the more conservative assumptions of Alternative I.

Since the United States under both alternatives is expected to supply by far the largest share of increased overseas demand for coarse grains, and the major share of increased import demand for wheat, we ought to know if such increases are within our potential. In a study prepared by the Economic Research Service at the request of Secretary Butz, this question was considered. The gist of the report is that American farmers have the potential to increase substantially their output of the major agricultural products. I must emphasize that the findings deal specifically with our potential; there was no attempt to predict whether that potential would be achieved. They were intended as a profile of what might happen under a specified set of conditions, namely:

—That farm product prices in the future are favorable for increased production;

—That there are no restrictions on the use of land;

—That supplies of inputs are adequate, and that they are made available to producers at relatively favorable prices;

—That growing conditions are normal;

—And, that new agricultural science and technology will continue to emerge at about the same rate as in past years, with neither new scientific breakthroughs nor drying up of the fountain of new knowledge.

How do the numbers come out? The conservative Alternative I implies that the United States would produce about 50 million metric tons of wheat in 1985; our production potential study shows about 60 million tons. As for coarse grains, under Conservative Alternative I, coarse grain production would reach 233 million tons; our production potential study indicates 315 million tons. The dynamic Alternative II indicates United States coarse grain production of 290 million tons, also well within our production potential. The subject of U.S. production capacity deserves a more thorough treatment than time permits, so I recommend that you read more details of these findings in this December's issue of the ERS *Farm Index.*

Before leaving this discussion of world trends in grain production and trade, I think some discussion of the assumptions underlying the analysis is necessary. Anyone can make a projection. All it takes is a straight edge if linear functions are your specialty, although the use of a French curve will give you more standing in the profession. What makes a projection useful is good judgment in selecting assumptions.

While we are aware of the debates among meteorologists and climatologists about possible cyclical patterns in weather or shifts in climate, the complexity of weather prediction remains mind boggling to the best independent observers, and I see no other reasonable assumption for now but that of "normal weather."

Population trends have great weight in the analysis. I think use of the U. N. medium projection puts us on conservative ground, although there is no question our knowledge of world population trends demands periodic reviews. The increasing importance of China to the analysis introduces possibilities of a greater margin of uncertainty because of the great size of her population and the meager information about it which is available.

Income growth rates are the result of the interaction of whole complexes of other economic, social, and political factors. In the aggregate they do not seem to change greatly over a period as short as a decade, and a continuation of past trends is assumed in the conservative Alternative I. Increased demand for livestock in the more dynamic Alternative II does imply a more rapid growth in consumer incomes in certain areas. Both alternatives assume that rising incomes will shift demand away from food grains and towards livestock products according to the pattern observed in the developed countries.

You may ask why we did not consider a pessimistic projection, based on diminishing supplies of energy and other natural resources, and a decline in the rate of economic growth. Such is the mood that seems to be attracting more and more followers. We have not thought this set of conditions to have probability high enough, during the time span under consideration, to warrant its inclusion.

The assumptions respecting the factors which determine production response of producers are perhaps the most critical and among the most difficult for which to obtain hard data. Our analysts feel reasonably confident that sufficient land and labor is available to support the production levels envisaged in 1985 under both the conservative and the dynamic assumptions. This is partly true for land because the bulk of production increases projected in both developed and developing countries is expected to come from increased yields. Still, moderate amounts of land seem to be available economically in the world, particularly in grain producing areas in the Southern Hemisphere. Higher levels of demand than assumed here would raise more serious questions about the economic feasibility of producing on more marginal land. As for farm labor, our analysts believe a relatively smoothly functioning labor market in the developed countries will signal a wage necessary to attract sufficient workers. In the less developed countries, the common condition of abundant labor in rural areas is expected to continue.

The projections under both the conservative and dynamic assumptions imply a continuous improvement in technology at a rate at least as high as that of the last decade, but do not require major breakthroughs in new knowledge. Production of grains is projected to increase faster in the LDC's than in the developed world. This is possible with a modest increase in area and with substantial increases in yields. Still, average yields in the LDC's in 1985 would be less than the average yields in the developed countries in the early 1970's. This difference is the basis for our analysts' belief that available technology should be sufficient to allow for the implied increase in yields in the LDC's. In other words, the developed countries have shown the way; the technological problem for the developing countries is how to adapt and apply existing technology. The problem for the developed countries is how to maintain the efficient operation of a technology-generating process which has proved extremely responsive to our needs in the past.

I am not so optimistic as to believe that the adaptation, transfer and application of technology in developing countries is a self-starting automatic process. We have had uneven successes so far in the "green revolution." We have had considerable success, for instance, in promoting increased wheat yields in the LDC's, but the work in rice has been less successful. As for the other grains, scientists in the developing regions are only now turning their attention to their study. But I came away from the CIMMYT Wheat-Barley-Triticale Workshop in Mexico last January believing that significant improvements are in the offing.

Just this past September scientists at Purdue announced the discovery of two naturally occurring strains of sorghums which possess a trait which makes them nutritionally far superior to other sorghums. Such sorghums provide the principal subsistence for more than 300 million people—people who are among the poorest in the world. The superior trait—larger quantities of the amino acid lysine essential to effective human utilization of cereal protein—is believed by the scientists to be easily transferred to other types of sorghums. It will take an estimated three to five years for plant breeders to carry out the cross-breeding and to supply seed for regular use.

Dramatic increases in production have been achieved so far in only a few countries. India is one of those countries which demonstrates that the "green revolution" is alive and well. India's severely drought-damaged grain crop in 1972 would have been substantially lower in the absence of high yielding varieties, fertilizers, irrigation, and the whole package of institutional measures such as farm credit.

Successful application and transfer of technology to the developing countries requires major changes and development of management and institutional arrangements. A growing and improved infrastructure is needed to support the larger requirements for production inputs and product marketing. Achievement of these aims in many cases may be more difficult than the theoretical and technical problems faced by the scientist in the laboratory seeking a breakthrough in soybean yields. The scientist and extension worker must join hands with the businessman, politician, and bureaucrat if the farmer's engine of technology is to be started and fueled.

The assured availability of adequate supplies of production inputs is extremely important to the analysis. It is a sobering, but I think essentially favorable, result of the conflict in the Middle East that we have been forced to focus our attention sooner than we might otherwise have done upon our long-range energy requirements. Somehow, I feel that governments throughout the world will find the maintenance of food supplies so fundamental as to give agriculture the priority which it deserves in the allocation of fuels.

Earlier I noted the existing tight situation in fertilizer supplies which was heightened by a developing scarcity of natural gas. The present fertilizer crunch has been building up since mid-1971. The over-capacity of the late 1960's discouraged new investment in fertilizer plants. Construction and operating difficulties inhibited production, especially in the developing countries where much of the new capacity, particularly for urea, is concentrated.

For the longer run, the present tight situation will undoubtedly result in more investment in nitrogenous and phosphatic fertilizer. These investments, however, may follow a different pattern than in the past as the developing regions consume more, and the more developed areas exhaust their most easily exploitable natural gas and phosphate rock deposits. Already several middle eastern countries are building nitrogen plants based on their vast natural gas reserves; Kuwait, for example, may now be the fourth or fifth largest exporter of urea (similarly, Morocco has become a major exporter of phosphate rock). Changing technology, depending upon the economic or political situation, could change this pattern. North America still has substantial reserves of "sour" natural gas, although processing it is more expensive than for "sweet" gas. Another possibility is that synthetic natural gas made from coal could become an economical substitute for natural gas.

Concerning projections, I would like to call your attention to an important new study by Iowa State University which deals extensively with the problems of projecting world food production. It is entitled, *World Food Production, Demand and Trade to 1985 and 2000.* Their approach and methodology are generally similar to ours but differ in some details and assumptions. Their projections deliberately exclude the effects of the "green revolution's" technological advances by projecting yields and production from data for the period preceding those advances. Their projections, like ours, suggest that the world has adequate potential to feed its foreseeable population for many years to come. However, their exclusion of the effects of the green revolution results in projections of large and growing import needs by the LDC's. They regard this eventuality as undesirable, but not inevitable, and they conclude that greater efforts must be made to advance agricultural technology in the LDC's.

Well, like Scrooge in Dickens's *Christmas Carol,* we have completed our review of past, present, and future. I like to think that I am more optimistic about world food prospects than was old Scrooge in his unreconstructed state, but also less prone to unjustified euphoria than he was following his spiritual transformation. If we fail to give world food problems the attention which they deserve, we run the same risk as Scrooge; we might wake up someday and not be sure whether we are still in the midst of a nightmare.

If we are to deal effectively with world food problems, I think that we have to give serious consideration to the following questions and issues bearing upon U. S. policies and policy alternatives for food, agriculture, and trade. These questions would be well worth considering at the forthcoming U. N. World Food Conference.

1. *Trends in world food production and demand.* Does our analysis capture the underlying trend through 1985? Will the U. S. need to "feed the world" by ever-greater amounts of food aid? Will we still have plenty of food to sell on commercial world markets?
2. *Population growth.* Can it be cut? How? And how soon? Ultimately unless the rate of growth in the world's population is checked, there is no solution to the world food problem. Long-range projections of present rates of population growth simply run off the chart and beyond the range of agricultural solutions that are either possessed or conceivable. We still have time, but we must begin to put it to good advantage now.
3. *Agricultural trade.* Can it be expanded? Expanded especially among the developed nations of the world through multilateral negotiations leading to trade liberalization and through a parallel reform of the world's monetary system?
4. *Agricultural trade between developed and less developed nations.* Can this trade be expanded to meet the difficult problems of how the poorer nations can best earn needed foreign exchange?
5. *Trade with Communist countries, especially the Soviet Union.* The USSR has accounted for major fluctuations on the world grain market. Every effort should be made to obtain better information from Communist nations about crop conditions, harvests, stocks, and marketing conditions if they expect us to supply them in the future as smoothly as we supply other customer countries which do provide such information.
6. *Stocks of key agricultural commodities and reserve proposals.* What are adequate stock levels? In whose hands should stocks be held? Who should bear the cost? What are reasonable objectives of a stocks policy?
7. *Emergency food relief and food support for friendly nations in crisis.* What is the best way to fill these needs now that the level of P.L. 480 shipments has been reduced? Should the U. S. produce specifically for food aid and disaster relief?

That should be a sufficient number of issues to challenge our best efforts at this meeting or, for that matter, at a large number of meetings over a long time to come.

Food Policy Issues in the United States*

LEO V. MAYER AND GARY L. SEEVERS

AFTER 20 YEARS of agricultural policy characterized primarily by government controls designed to constrain the production of farm products, agricultural policy in the United States has recently undergone a major reversal. Beginning in late 1972, agricultural policy became production-expansive, with agriculture now freed of most restraints on production in order to meet domestic food needs and a potential $20 billion export market. At the same time government controls over much of the remainder of the food sector, which were relatively minor or nonexistent during most of these 20 years, have increased greatly since August 1971. Both developments—fewer controls on the farm sector and more controls on the food sector—have occurred in response to a growing worldwide scarcity of food.

The public discussion over food prices and policies continues, with analysts divided over issues and solutions. Some emphasize the need to manage exports, others the merits of expanding exports; some the need to build buffer stocks, others the pitfalls of planned stockpiling; some stress all-out production, others the dangers of contributing to a boom-bust farm economy; some argue that food shortages endanger general price stability, others that they burden poor countries via diminished food assistance; and quite a few are quietly waiting for the return to days of surpluses and support-level prices.

Many unresolved issues on food policy remain with us in 1974. This paper is an initial attempt to outline the food policy problems facing this nation in the mid-1970's—problems that have taken on national and international significance. These issues command an important set of consequences for many millions of people.

The Complexity of National Food Policy

To appreciate the difficulty of developing a consistent national food policy, one must appreciate the vast set of variables involved. With the tightening in nearly every conceivable dimension of food markets in the past two years, national food policy must take account of a more complex set of interrelationships. While this was always true, only a few quarters ago large carryover stocks of many crops were available to offset production shortfalls or planning errors. Also, idle crop acres allowed individual program decisions to be considered in isolation. Any increased need for land could be taken from a stock of idle crop acres. There was no need for concern over competition between crops and livestock; excess crop acres provided a margin for expansion of both. Further, underemployment of labor and capital resources provided the complementary inputs, and planning could safely assume ample supplies of fuels, fertilizers, and insecticides. These circumstances led to an environment in which specific policy decisions involved relatively few variables and considerations.

In the past year all that has dramatically changed. There is far less slack in the economic system, both farm and nonfarm. Food policy must be formulated under conditions with far more widespread consequences for every decision, and each decision intersects with almost all others. The commodity-by-commodity approach that has often dominated operational policy analysis over the decades is being questioned as excess production capacity and abundant inventories of farm products disappear. Today a much more comprehensive approach is necessary to reflect the increased complexity of food policy. The development of such an operational framework remains a goal for the future. In the absence of such a framework, our comments will be organized to focus on three types of food policies: supply policy, marketing policy, and demand policy.

Supply policy

For most of the past 40 years, food supply policy in the United States has concentrated on control of crop production and restraints on food imports. With excess capacity available, supply policy limited crop production and provided for purchase and storage of excess output. With a potential for excess livestock production due to underemployed labor, abundant grassland, and abundant grains and concentrates, an effective system existed for orderly but controlled expan-

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sion of total food supplies. Supply policy was relatively simple: control production and support prices to adjust grain and oilseed production to meet domestic and export needs. Price support loans removed a measure of market risk to crop producers. Only during war did policy seriously concern itself with expansion of farm production.

In the late 1960's it appears that the situation began to change. It is not clear yet whether producers, especially livestock operators, began to focus more heavily on prospective market returns, more on increasing off-farm job opportunities, or less on the status traditionally associated with farming and ranching. Perhaps labor resources in agriculture finally reached an equilibrium with requirements of normal years. Whatever the actual structural shifts, the outcome was a leveling out in the production of food for domestic consumption.

The primary impact occurred in output from the animal sector. The index of animal products available to consumers climbed 14.8 percent between 1960 and 1967, but the same index increased less than 1 percent between 1967 and 1973. A temporary surge in pork production in 1970–71 overshadowed this trend, but as that overexpansion ended, the production trend again resumed its lower slope. Pork production slowed, and sheep and dairy cow numbers continued downward mainly due to competition from beef cow herd expansion and tight labor supplies. Total supplies of red meat began to stabilize. Following the initial export boom in mid-1972, the buoyant cash market for grains and soybeans caused many producers to retreat from traditional livestock production. And the guaranteed market prices for crops and uncertain markets for livestock tended to discourage livestock production because of the relatively greater risks involved.

Indeed, the only major commodities left principally to the market place were red meats and poultry. When there was abundant feed, labor and complementary resources, the greater risk in production of livestock had little impact on supplies. As markets tightened, however, and labor resources became more scarce with more attractive off-farm job opportunities, the risk differential became more important. National food policy with its emphasis on the crop sector became less effective in meeting the demands of consumers who were shifting away from cereals and toward meat and protein products. The government programs aimed at regulating crop production, coupled with a policy of export expansion mainly for crops, raised serious problems. The greater degree of market certainty for crops tended to bias resource use, whether in shifts of fertilizer onto crops and away from grass, or in shifts of land out of grass and into crop production or government programs. Examined from the view of a country that is demanding more meat and protein, the past concentration of policies on crop production must be questioned.

Another question associated with food supplies is the appropriate policy on grain stocks. For decades, supply policy has included a heavy element of carryover stocks of primary agricultural commodities. Their existence came as a means of supporting farm prices. As a derivative, the nation was provided insurance against shortfalls in domestic production—or sharp expansions in export demand. This stability protected consumers against large fluctuations in the price of food. But these stocks also had high budget costs and were generally viewed as a burden. In the process of reacting to this problem, policy assigned a heavy weight to ridding the country of burdensome stocks. Policies were adopted to improve the "fine tuning" of control programs in order to mesh output with prospective demand. Price supports were lowered, especially in real terms, and accumulated stocks were disposed of through food aid and subsidized exports.

With the sharp rise in commodity prices in the last year, the role of stocks has again come to the forefront. There is a possibility that no rebuilding of grain stocks will occur under the new farm legislation unless world food conditions change dramatically from their current state. An important question is whether a policy of only commercial stockpiles will be a sufficient safeguard against excess demand situations in the future. Will current policies provide adequate stockpiles to prevent periodic upsurges in prices? What other mechanisms can be developed to guard against large upside risks comparable to the mechanisms that protect farmers against downside risks? Can a stocks policy be developed that is consistent with the objective of a maximum amount of market orientation for the private sector and a minimum role for the public sector? Is a stocks policy that differentiates between domestic and export markets feasible? These are important questions for food policy.

Marketing policy

Measured in value terms, the marketing share of food products represents considerably more than one-half of the cost of consumer food sales.

Measured in terms of policy emphasis and program expenditures, it has represented far less over the years. Public expenditures on improving the flow and quality of products moving across retail checkout counters are relatively insignificant compared to either supply or demand expansion policies.

One major element of marketing policy is a set of grades and standards established in an earlier day to facilitate the orderly movement of food products. Times changed. The mix and quality of products shifted, merchandizing methods went through a revolution, but the regulations remained largely static, partly performing their original function of coordinating commodity movement but also affecting the mix, quantities, and quality of products produced and supplied to markets.

The broad impact of grades and standards regulations on the efficiency of farm production or even retailing economics is only speculative. More questions need to be raised as to the degree of imperfection they place in market processes.

For some food commodities, grades and standards were inadequate. Variation in seasonal and annual flows often resulted in skyrocketing prices at one point of time and depressed prices at another. To combat these fluctuations, a more rigorous set of marketing order and agreement programs were established. Legally binding agreements were made available to grower groups. Once in place, producers could market only products that met certain size, quality, or volume requirements. These regulations tended to raise the average quality of products sold to consumers, but also tended to make less total quantity of product available to the market. They also tended to replace part of the function of grades and standards; consumers did not have access to the lowest quality or smallest size of a product controlled.

As with commodities covered under price support programs, the supply conditions of market order and agreement commodities were not dramatically altered by government policies. Excess land and labor provided a capacity for overproduction that benefited consumers in spite of government organized programs of market control. However, the advent of tight resource conditions in 1972 and 1973 coupled with rapidly growing consumer demand brought new buoyancy to markets for these commodities.

The new market environment has not eliminated marketing order programs, however. Established under permanent legislation, there are legal limits to the administrative changes allowed. While the structure of many fruit and vegetable markets has changed dramatically as producer or processor cooperatives expanded their operations, these programs still give additional control to and typically are run by grower groups. Did public officials ever foresee the double source of bargaining power that the Capper-Volstead Act of 1922 combined with the Marketing Act of 1937 would give many producer organizations? Indeed, what is the appropriate concept of producer to be employed in connection with the Capper-Volstead Act?

In any event, the change in market composition provides a very different competitive situation in many links of the marketing-processing-retailing chain today. These programs need to be reexamined, not for fine tuning as occurred during the past three decades, but for the kind of thorough review and change that occurs periodically for general farm legislation. Would a consistent set of grades and standards along with consumer education on their meaning be a satisfactory replacement for the programs of controlling or stabilizing commodity marketings?

Conventional marketing institutions—grades, orders and cooperatives—are significant in their own right but are by no means the most important public policies affecting food marketing. Transportation accounts for a large fraction of the final cost of food and this is a sector that has had to function under an extraordinary burden of government regulation. Primarily as a consequence of that regulation, the transportation industry is far less efficient than it could be and that affects the cost of food. Efficiency in the food sector is also affected by many other policies. The National Commission on Productivity recently completed a thorough review of productivity in the food sector and made recommendations that are worth reviewing.

Price and wage controls, of course, represent the main form of government intervention in food marketing at present. In fact, many of the most interesting questions today are associated with the controls and can be examined only by considering the food sector as a whole. What has been the impact of price controls on productivity and efficiency in food marketing? How have they changed traditional relationships, and is this desirable? Has the pass-through system of price controls, with raw products exempt, really controlled food prices, or has demand simply bid up farm prices and thus cost-justified price increases all the way up the food ladder? And perhaps most important, have controls on food marketing affected the supply of farm products even though they were not directly controlled?

Demand policy

To round out this review, we want to discuss briefly the policies affecting demand for food. Events of the past year have demonstrated that far more flexibility exists in consumption of food than most of us believed. Total food consumed per capita in 1973 was down 2 percent, protein consumption was down 4 percent, and meat consumption was down 7 percent. There have been some sharp shifts in eating habits. Consumption of fresh fruits was unchanged, processed fruits up 5 percent. There have been other shifts, especially in dairy products, where small price differentials have brought large changes in consumption habits.

Changes in food consumption this year are primarily reactions to changes in relative prices. The reductions occurred despite attempts to increase food availability through sharp cutbacks in P.L. 480 and commercial export subsidy programs.

In contrast to cutbacks in export expansion programs, there has been a sizable increase in domestic food assistance programs. Federal expenditures are running nearly 8 percent higher than a year earlier. Even so, the sharp run up in food prices has meant less real value from food assistance programs.

P.L. 480 and domestic food assistance programs focus attention on the trade-offs that exist in policy between satisfying needs of low-income domestic food consumers, low-income foreign consumers, and domestic consumers ineligible for food assistance. These two programs are by no means our total policy affecting the demand for farm commodities. There is an abundance of programs developed throughout years of surplus supply conditions to encourage exports to other countries. These have included direct subsidy of commodities for export, differential pricing of sales from CCC stocks, provision of low cost CCC credit, use of Import-Export Bank credit to facilitate sales, and other minor methods of acquainting foreign consumers with products and commodities that are available for export. These varied programs enlarge the demand for U. S. farm products overseas. They have operated more or less independently of efforts to provide domestic consumers with adequate supplies of food products. This differential approach in administering policy to satisfy foreign and domestic food demand has brought about some sharp conflicts in the past year. Curtailment of livestock production as feedstuff prices rose caused a temporary embargo on exports of oilmeal products, a clear demonstration of the conflict between domestic food demand and export demand.

The trade-off between domestic and export markets raises an obvious question: Should the government continue a policy of agricultural export expansion, and how vigorously, when this leads to more expensive food for our own consumers? This issue becomes especially significant when one recognizes that U. S. markets provide a major share of the rationing function among the industrial countries of the world since many other countries isolate their domestic food markets. Is it in the interest of the United States to absorb a significant share of the adjustment to the fluctuations of world agricultural production? These issues will be faced in coming months through various international and national forums.

Conclusions

Food policy now has several dimensions that increase the difficulty of analysis, the complexity of decision making, and the urgency for improved information and research on all facets of food policy. The aggregate data on farm production clearly indicate problems—before 1967 crop and livestock production grew at nearly equal rates. Since 1967 crop production increases to meet export needs have far exceeded increases in livestock production for domestic use. The reasons are many, but that only makes additional analysis more urgent.

There is also a need for integration of different policy issues. We can no longer analyze export policies independently of domestic utilization and stock policies, if ever that was realistically possible. Just as transportation and storage capacity are more interrelated than realized a few years ago, the role of grain stocks is more related to export capability and to domestic food availability than previously recognized. A broadened focus is required to identify all facets of the policy issues that are emerging.

Finally, while events of the last year have shown that important changes in policy can be made, they have also shown how difficult and time consuming it is to bring about reform of long-established policies, programs, and ideas.

Recommendations for policy changes or even administrative changes in programs face an uphill battle even in times of immense national pressure. There must be a very large improvement in the welfare of some market participant(s) for government to undertake the large administrative effort to effect change. This reality argues for future policy analyses that focus on issues with broadened clientele and more comprehensive impacts than in the past.

U. S. Policies for Food and Agriculture in an Unstable World*

LUTHER TWEETEN AND JAMES PLAXICO

THE Agriculture and Consumer Protection Act of 1973 has much to recommend it. If farm organizations do not give it outright support, at least they show little overt opposition. We detect consensus even among economists by and large toward a program of low price supports, flexibility, and market orientation not unlike the provisions of the Act. Few economists today call for either a free market or strict supply management. The 1973 Act does not unduly encourage overproduction—marginal output receives the market price or loan rate (set so low it can hardly be viewed as a generator of surpluses or undue infringement on operation of the market) rather than the higher target price used to set direct payments.

A most notable feature of the 1973 Act is its flexibility, with management of set aside and other features largely at the discretion of the Secretary of Agriculture. To a greater degree than in previous legislation, "policy" is replaced by management decisions made continuously or at least annually rather than only when a new farm bill is drawn. As such, the 1973 Act entails challenges and opportunities as never before. This paper deals with those challenges and opportunities, suggesting directions for administering the Act to meet desirable objectives of commercial farm policy.

Current prominence of food and farm issues emerged from highly visible and unusual retail food price increases and the newly recognized potential of agriculture to ameliorate trade balance problems. One high official in the federal government stated that "agriculture is now too important to leave to the agriculturists." While the unfortunate food price ceiling imposed in 1973 largely by non-agriculturists gives no basis to conclude they are superior managers of agricultural affairs, we still make a case in this paper that consumers have a large stake in farm policy that cannot be overlooked.

Following a brief review of long-term trends in supply and demand, we examine issues of uncertainty in the supply and demand for farm output and how to administer a farm program in keeping with the needs of domestic farmers, consumers, and taxpayers as well as of persons in foreign nations. Particular emphasis focuses on a food reserve policy to reduce uncertainties.

Review of Long-Run Outlook for the Farm Economy

This section shows a balance between anticipated shifts to the right in demand and supply (due to productivity) to 1985, and reserve capacity in line with export demands. While there can be no doubt about the capacity of the American farming industry to meet anticipated demands, the balances are shaky and veil the problems of accommodating farm policy to the need for stability in an inherently unstable world.

Shifts in demand and supply

Domestic demand for farm output can be predicted with considerable accuracy. Optimistic estimates of growth in domestic demand from 1973 to 1985 based on an annual population increase of 1.0 percent, annual real income gains per capita of 3 percent, and an income elasticity of .15 place total annual gains at 1.0 + .3(.15) = 1.45 percent. Less optimistic estimates of growth in domestic demand for farm output based on an annual population gain of .6 percent, annual real income gains per capita of 2 percent, and an income elasticity of .10 place total annual gains at .6 + .10(2) = .8 percent.

In regard to the highly elusive export demand, optimistic estimates place annual growth from the 1973 base of no more than 4 percent (exports may drop in the mid-1970's as evident in the more comprehensive later discussion of export prospects). Pessimistic estimates indicate no gain in exports for 1985 over 1973. Combining the most optimistic foreign and domestic estimates, and with 20 percent of output exported, total annual growth in demand for farm output is .8(1.45) + .2(4) = 2.0 percent. Combining pessimistic estimates, total annual growth in demand output is .8(.8) + .2(0) = .6 percent. This range of predicted average annual shifts in demand is comparatively small, and the farm

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prices at which it can be supplied depends on reserve capacity, productivity, and supply response to price.

Whether shifts in supply can keep pace with the annual gains in demand depends on productivity. Weather makes the productivity ratio of output to production inputs erratic, but, on the average the ratio expanded 1.5 percent annually in the decade preceding 1972. There was virtually no gain from 1965 to 1970 but a 7 percent gain in 1971. Since the denominator of the productivity ratio includes diverted acres as production inputs, the cut in diverted acres and attendant increase in output accounts for a considerable portion of the large gain in 1971. Adjustment of the productivity index for this factor suggests that "real" annual gains in the past decade averaged about 1 percent. If this trend is projected into the future, it appears that the lower estimate of shifts in demand can be met with no gain in the ratio of prices received to prices paid by farmers. However, productivity gains slowed by energy and fertilizer shortages, and coupled with general inflation, will cause both prices paid and received by farmers to rise substantially by 1985.

Reserve capacity and increased exports

Reserve capacity (net diversions of output by ASCS acreage withdrawal, net CCC stock accumulation and an appropriate portion [1] of P. L. 480 exports) by one measure averaged 6 percent in the 1962–69 period [6]. That was also about the level of capacity left idle in 1972 by diversion of 63 million acres by the government programs. The quantity of exports increased one-third in fiscal 1973 and translates into a 5 percent gain in total demand for farm output. The reserve capacity has been released slowly in response to demand and 19 million acres continued to be diverted in 1973. Approximately 3 million low productivity acres will be held out of production in 1974 by long-term contracts. Since the price elasticity of demand for farm output is approximately —.2 in the short run in the absence of adequate stocks, the gains in export demand coupled with some gain in domestic demand could be expected to raise prices 25 percent—that is what happened.

In estimating reserve capacity, Quance and Tweeten [6] assumed yields on diverted acres would have averaged 80 percent of those on acres in production and that 63 percent of acres diverted under long-term contracts and nearly all acres diverted by the short-term programs would return to production in the absence of programs. While empirical estimates [12] indicate that yields on diverted acres would average 90 percent of yields on acres in production, and consultation with persons in the U. S. Department of Agriculture intimately associated with research on diversion programs suggested that program provisions were keeping out many acres of cropland that a free market would bring in, still, in perspective the Quance-Tweeten estimates of reserve capacity appear high. Experience from 1971 and 1973 suggests that only half as many acres would return to cropland as were diverted. In a fine recent book, Professor D. Gale Johnson [4] estimated that past reserve capacity was only 2 percent of output. This estimate appears on the low side, however, for several reasons. It does not include the portion of P. L. 480 exports imputed to reserve capacity. It does not account for the fact that some diverted acres and new cropland take more than one year to be cropped at 1960's prices because of inertia, uncertainty, and other reasons. It does not account for the productivity of forage production on diverted acres not returned to crops—with improved management these acres can be productive when cattle prices are high. Nevertheless, even with adjustment for these factors, reserve capacity probably averaged no more than 4–5 percent in the decade preceding 1972. Bringing in all reserve capacity can meet the new level (up one-third from 1972) of export demand at or near the ratio of prices received to prices paid of 100, quoted with a 1967 base.

This seemingly comfortable balance of reserve capacity with the 5 percent gain in exports and the approximate balance of trends in demand with those in supply suggests no call for a sharply higher ratio of prices received to prices paid by 1985, but masks massive uncertainties to be discussed below. Among the factors, the latent supply response at home and abroad generates a cobweb effect. The U. S. supply elasticity for farm output has been computed to be .15 in the short run, .3 in the intermediate run, and 1.5 in the long run for increasing prices [9]. The 1973 level of farm commodity prices generates output that will create new supply-demand balances and prices. If the additional supplies in 1974 and 1975 generated with a lag by high prices in 1973 are combined with lower exports, the result could be a considerable drop in prices received by farmers in the mid-1970's.

It seems clear that American farmers have sufficient capacity to meet our best estimates of the most likely supply and demand for food and fiber to 1985. What is unclear is how elements of uncertainty will buffet this knife-edge balance and how the Secretary of Agriculture and farm policy legislation will cope with these elements discussed below.

Elements of Uncertainty

Key elements of uncertainty are domestic weather, public policy, and exports.

Exports

In August 1972, speaking about export prospects, West [13] stated "under favorable conditions, I think we can reasonably expect to reach the $10 billion level by or before 1980." D. Gale Johnson [4] asserted that "available evidence indicates that if present farm and trade policies continue unchanged throughout the present decade, U. S. farm exports could decline (comparing 1970)." These views by persons highly knowledgeable about world trade serve as a caution to those who would aspire to success in predicting farm exports.[1]

Economists failed to predict food price increases in 1973 because they lacked knowledge of the magnitude of certain variables such as the Russian wheat crop and because they lacked knowledge of key parameters such as the response of exports to devaluation. Without a measure of the response of export demand to changes in relative prices through devaluation, it is impossible to separate the permanent from transitory elements of demand.

Lack of economic research on the response of exports to price and the widespread practice of assuming a zero price elasticity of export demand for farm products [e.g., 2] is indefensible. Devaluation is predicated on the assumption that exports do respond to terms of trade and that lower prices will improve our balance of payments. The intermediate-run export demand elasticity with respect to prices received by farmers had been estimated to be —2 [7]. The short-run elasticity may be —1 with inventory demand included. These estimates apply to changes in U. S. export prices of our farm commodities and not to the concept of interest here, namely devaluation which reduces prices of all U. S. goods relative to those of other countries.[2] If food is a substitute for other items, then a given percentage reduction in the price of farm output alone could be expected to bring about a greater change in quantity demanded than a comparable percentage devaluation through the substitution effect (although the income effect of devaluation is greater). Nevertheless, the price elasticity of demand for exports can be used as a crude measure of the impact of devaluation. Overall dollar devaluation, based on average change in terms of trade weighted by quantities of trade, has been approximately 15 percent [11] over the past two years. As such, half of the 1973 and 1974 gains in export quantity may be the result of devaluation based on an elasticity of —1. If current terms of trade continue, and a price elasticity of —2 applies in the intermediate run then the quantity of exports near recent levels (up one-third since 1972) can be attained in the later 1970's. Of course, revaluation, changes in trading restrictions, and abnormal weather can easily change this relationship.

Another approach is to project exports by separating permanent and transitory components by country. U. S. Department of Agriculture data [10] show that, of the increase in U. S. farm exports in fiscal 1973 as compared to the previous year, 16 percent was accounted for by Russia, 22 percent by Japan, and 30 percent by Western Europe. Weather, a transitory factor, was undoubtedly the major but not the only, factor explaining grain sales to the Soviet Union. On the other hand, non-weather factors probably explain the majority of the increases going to Japan and Western Europe, although transitory elements such as the fish catch off Peru and crop conditions in countries competing with the U. S. were also factors. These data suggest that approximately half of the short-term gains are transitory rather than permanent components; this figure is in line with the estimate from the short-term price elasticity.

A third way to project exports is from projected imports—with appropriate assumptions about balance of payments and farm export shares. Declining domestic oil reserves and the gap between increasing domestic demand for petroleum and declining domestic oil production led to projections by informed sources [5] of $25 billion to $30 billion of oil imports by 1985. To pay for such imports, huge exports and foreign investment in the U. S. would be required. Floating exchange rates would make terms of trade and imports from the U. S. for those acquiring dollars an "offer they can't refuse." Since the U. S. holds a comparative advantage in production and export of farm commodities, a principal beneficiary would be U. S. farmers. Of course, some of the deficit would be made up by purchase of non-farm commodities and investments in this country—the entire oil deficit of $25–$30 billion would not accrue as additional income to American farmers. A totally different scenario emerges in the face of tight oil supplies from the Middle East. President Nixon publicly committed this nation to energy self-sufficiency by 1980. Imports are interrelated, and if we import drastically less we will also export less.

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[1] U. S. Agricultural exports in current billion dollars and quantity indexes (expressed as percent of fiscal 1970 in parentheses) are as follows: $6.6 (100) in 1970, $7.7 (108) in 1971, $8.0 (108) in 1972, $12.9 (143) in 1973, and a projected $19.0 in 1974.

[2] Terms of trade shifted at least proportionally to devaluation on only 40 percent of U. S. farm exports, a percentage that interestingly enough exactly corresponds with that used in 1967 by Tweeten [7] in calculating long-run export elasticity. One-third of our farm exports went to nations which devalued with us. The remaining exports went to countries which permitted these currencies to change in value relative to the dollar but restricted trade to a degree with quotas and other devices.

Countervailing power and the export market structure

Shortages in food and energy highlight two points: the value of self-sufficiency and the power of small nations acting in concert. Neither augurs well for trade. Shortages stimulate development of substitutes purchased from other sources (e.g., soybeans from Brazil) or generated by research (e.g., vegetable proteins replacing meat). The principle of countervailing power suggests that existing blocs such as the EEC will become more cohesive and new power blocs will form to countervail the influence of the Arab oil bloc. An obvious example is a food power bloc composed of the United States, Canada, and Australia to confront the EEC, Arabs, and communist Europe. A food power bloc would reduce trade by restricting exports, or it could be constructive and enhance trade if used as a bargaining tool to reduce trade barriers of the EEC or Japan.

A food bloc could require changes in the export structure of U. S. marketing firms. The grain sale to Russia highlighted the weaknesses of fragmented export firms (even though U. S. firms are comparatively few in number) in dealing with a single buyer of large quantities. Each U. S. firm was unaware of the trades negotiated with other firms by Soviet officials. The total quantities, also unknown to U. S. firms, were large enough to give substantially higher prices under a new supply-demand balance—that too was discovered only after the fact. The U. S. export marketing system is geared to an atomistic structure of marginal sales that do not materially influence industry price. Can such a structure with attendant large losses to U. S. farmers and consumers endure at acceptable cost?

It is easy to conceive numerous scenarios depicting future demand and supply of U. S. farm output in an unstable world. It is also apparent that no one scenario has great credence. Since we cannot predict the future very well, we must confront the issue of how to live better with uncertainty.

Consumers' Support for Reserves

With the rhetoric supporting an "ever normal granary" now widely known and the value of reserve capacity demonstrated repeatedly since the Biblical account of Joseph, further discussion of the need for reserves appears to belabor an obvious point. Yet there are several reasons to reaffirm the case for reserves.

Support by the agricultural establishment and government leaders for reserves is weak [see 3]. Farmers have observed that the very existence of large stocks of farm commodities depresses prices, and large gains in farm prices and incomes in 1973 came only after government stocks were depleted. Farmers support a modest strategic reserve to raise prices temporarily as purchases are made from the market, but favor "throwing away the key" except for catastrophic occurrences. Furthermore, farmers need not seek income security through manipulation of reserves of resources or stocks if income can be stabilized by direct payments in the 1973 Act.

The loan rate for corn has been set at $1.10 per bushel, a minimum to avoid financial hardship for farmers. The target price of $1.38 will be retained to 1976. With energy shortages and other factors contributing to inflation, the minimum price required to avoid financial hardship to farmers by 1976 may be 25 percent above $1.10, or $1.38 per bushel. Reserves were accumulated less by design than by default to support prices above loan levels in the past. Current programs may not generate these circumstances, since the supply response could be sufficient to hold prices above loan levels of $1.10 for corn and $1.37 for wheat by 1976. If reserves are desired, a conscious policy of accumulation is needed. Major benefits could accrue from sharing the burden of carrying reserves with other developed countries. We are not optimistic about getting an agreement. Advantages of the U. S. being a dependable supplier may justify our holding reserves even in the absence of an international agreement to share costs of holding reserves.

Consumers have much to gain from food price stability. Perhaps the impetus for reserves and stability will come from them. The emerging role of the consumer in farm legislation is symbolized by the titles of legislation since 1960: the Agricultural Acts of 1961, 1964, and 1970, the Food and Agriculture Acts of 1962 and 1965, and the Agriculture and Consumer Protection Act of 1973.

Economic theory and instability

Based on economic theory, consumers can be expected to become unusually disturbed when items such as food with low income elasticity of demand and few substitutes are in short supply. A low income elasticity also means a very low (absolute value) price elasticity of demand for such items.[3] Viewing the demand curve as a marginal utility curve, a low price elasticity means that consumers place great value on having enough of a good and very little value on having more. Deviations from the ideal could be corrected immediately if supply were highly elastic, but supply of farm output is not very responsive to price except in the long run. It is in such instances of inelastic supply and demand that reserve capacity is of pronounced value.

The case for stability is also strengthened by the disutility that attends income transfers among equals. Although shortages have not been severe, they suggest an often overlooked aspect of utility functions; after becoming accustomed to a given level of consumption, there is considerable disutility in moving to a lower level. If the marginal disutility from losing a dollar is greater than the marginal utility of gaining a dollar, redistribution among equals entails a social cost.

Overvaluation of the dollar had marked distributional effects. Overpriced U. S. commodities in the world market reduced our farm exports, held the domestic food price low, and transferred income from farmers to domestic consumers. The redistribution as measured by changes in consumers' and producers' surpluses is very large for commodities such as food with very low price elasticities of demand and supply at least in the short run. Accumulation by foreign countries of dollars (that were later devalued) transferred income from foreign countries to U. S. consumers.[4] Finally, the overvalued dollar and attendant balance of payments problems dealt a severe blow to U. S. foreign aid to food-short developing countries, again with major redistributional effects. Fortunately floating exchange rates have retarded or reversed these often perverse distributional impacts listed above.

Other points can be made for reducing instability. The contribution of forward pricing to efficient production has long been recognized. The advantages of reserve capacity in the drought of the 1930's, three subsequent wars, the corn blight of 1970, and the food crises of 1966–67 and 1972–73 are also apparent. Taxpayers seem to approve of stockpiling strategic commodities such as certain metals; food too would seem to be critical. Manufacturing industries operated at only 84 percent of capacity from 1962 to 1972, and the social cost of excess capacity in agriculture is small in relation to manufacturing as well as in relation to the cost as measured by percent of GNP. Man seems to overestimate reserves of finite resources such as petroleum and underprices them until they begin to run out; on the other hand, he tends to underestimate the capacity to find substitutes through research and other avenues for his ingenuity. While these two factors, the first causing underpricing and the second overpricing of commodities, may offset each other, again the advantages of holding reserve capacity to deal with miscalculations is hard to overrate.

Managing reserves

Farm commodity programs do not raise net farm income to pay living expenses over the long run because pecuniary benefits are bid into the price of land, but programs do have real value to create stability and can be designed and operated within this perspective.

Two polar policy options face the Secretary in the 1973 Act: (a) high set aside requirements and high market prices, or (b) low set aside and low market prices, with farm income maintained under the latter alternatives by storage or purchase of commodities under nonrecourse loans and by cash payments based on the difference between market prices and target prices. Farm incomes potentially can be stabilized with either approach, and the farmer may be indifferent.[5] The consumer is not, however. At issue is the degree of reserve capacity held in storage stocks and set aside acreage (or other unutilized resources) and the value of stability to the consumer.

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[3] If the demand function is homogenous of degree zero in prices and income and if the cross price elasticities are essentially zero for lack of substitutes, then the income elasticity is equal but opposite in sign to the price elasticity of demand.

[4] Neo-mercantilism in countries that accumulated dollars (later devalued with attendant loss of buying power) rather than "wealth of nations" in the form of goods and services consumed by their inhabitants and continued subsidization of dairy product sales to American consumers seems irrational. The impetus for exchange rate reform came more from the U. S. than these countries. This chimerical behavior testifies to the weight placed on full employment and the power of producers *vis-à-vis* the power of consumers.

One approach is to choose an optimal reserve policy by minimizing the net social cost over time. Tweeten, Kalbfleisch, and Lu [8] used dynamic programming and simulation procedures to do this for wheat, and found the optimal target carryover to be 400 million bushels to which should be added a "pipeline" stock perhaps of 200 million bushels. Some conclusions of that study are:

(1) The social cost of reasonably adequate reserve policies is comparatively small, averaging approximately 5 percent of net farm income.

(2) It is neither possible nor desirable to remove all price and income instability through supply control and inventory management.

(3) Government intervention on the demand (supply) side tends to require intervention on the supply (demand) side. Programs to regulate stocks tend to require programs to adjust acreage so expected production equals expected utilization plus target carryover.

(4) Commodity stock operations which release stocks when market price exceeds at least 20 percent of a target price and acquire stocks when the market price falls at least 20 percent below the target price display many useful features. One useful feature is the ability of such a policy with a somewhat wide intervention margin to operate fairly well when the target price is incorrectly set at a level that does not correspond to the long-term equilibrium market price.

This target carryover of 600 million bushels appeared to be considerably in excess of what a free market would carry, although the latter estimate for private traders was based on outdated data from years when wheat markets were relatively free of government intervention. Imperfections in the capital market and personal risk undoubtedly limit the reserves private enterprise would carry, and reserves held by farmers may be released inappropriately in panic selling. Since the very existence of reserves seems to depress prices received by farmers, and farmers can have stability through direct payments, a major issue now is the value placed on reserves by consumers. The issue is not whether Americans will have enough to eat in years of unfavorable weather —domestic consumers can have food merely by terminating exports which constitute 20 percent of output. Rather the issue is more variable prices and food budgets that would attend a free market versus less variable prices and food budgets (more costly in terms of mean food outlays or taxes) that would attend a well managed reserve.

Consumers' attitudes

It is useful to examine briefly perceptions by consumers of government action to reduce variation in food prices through reserve management policies. Views of 76 urban consumers between 18 and 65 years of age interviewed at random in shopping centers during late November and early December 1973 in three cities in Oklahoma are summarized in Table 1. The pilot study by a graduate class in agricultural economics was designed to present broadly realistic tradeoffs between the level and variability of food prices under a well managed reserve policy. Consumers seem willing to pay for more stable food prices and costs—respondents who preferred spending 20 percent of their income on food each year outnumber those who preferred spending 17 percent one year and 21 percent the next or vice versa by nearly two to one (Table 1, question 1). The 29 percent who preferred the less stable situation would pay an average of 19 percent of their income for food.

Despite the willingness to pay for stability evidenced in question 1, only 36 percent of the consumers favored some government control of supplies to achieve this end (Table 1, question 2). Of those who favored some government control, one-third favored only storage ("the government should store commodities when food prices are low and place the reserve stocks on the market when food prices are high"), 15 percent favored only production control ("the government should keep cropland out of production when food prices are low and bring the cropland into production when food prices are high"), 30 percent favored both storage and production controls, and 21 percent were undecided. Of the 25 who favored storage, 8 respondents favored more storage activity than in the past, 9 favored

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[5] Wealth gains might also include, with net farm income of $26 billion in 1973, an equal value of capital gains accruing to farmers who own farm real estate.

Table 1. Number of Oklahoma consumers interviewed who responded as indicated to food price stabilization questions (percentages in parentheses)

Question	Stillwater	Tulsa	Oklahoma City	Total
1. Over the next two years, if you had your choice, would you rather (Choose one)				
Spend 20% of your income each year on food	12	12	14	38 (50.0)
Spend 17% the first year, and 21% the second year on food	2	6	1	9 (11.8)
Spend 21% the first year, and 17% the second year on food	4	6	3	13 (17.1)
Don't know or no opinion	6	1	9	16 (21.1)
	24	25	27	76 (100.0)
2. Some consumers favor having the government help control food supplies from year to year to get more stable food prices. Other consumers favor allowing food prices to fluctuate from year to year to achieve more efficient food production under a free market. Which do you prefer?				
Some government control of supplies	10	11	6	27 (35.6)
No government control of supplies	13	14	20	47 (61.8)
Don't know or no opinion	1	0	1	2 (2.6)
	24	25	27	76 (100.0)
3. What proportion of their food budget do you think consumers and taxpayers would be willing to pay to get more stable food prices from year to year?				
	2	0	0	2 (6.9)
1 to 2 percent	1	3	1	5 (17.2)
3 to 4 percent	4	5	2	11 (37.9)
5 to 6 percent	0	0	1	1 (3.5)
Over 6 percent	0	1	0	1 (3.5)
Don't know or no opinion	4	2	3	9 (31.0)
	11	11	7	29 (100.0)

"about the same," 4 favored less, and 4 were undecided. Of the 19 who favored production control, 6 preferred more, 4 the same, 7 less than in the past, and 2 were undecided.

Those who favored some government control or were unsure in question 2 were asked how much consumers and taxpayers would pay to get more stable food prices (question 3, Table 1). A plurality of 38 percent said "3 to 4 percent" of their food budget—a figure in line with the cost of such public policies during the last decade.

The conclusion is that consumers are willing to sacrifice to obtain more stable food prices, but they lack confidence that government can manage reserves for stability based on past as well as recent decisions made by the federal government in nonagricultural as well as agricultural matters.

Summary and Conclusions

The balance outlined in this paper between shifts in demand and supply on one hand and between reserve capacity and a new export plateau of recent years on the other hand is reassuring—our farming industry has sufficient production capacity to meet demands placed on it to 1985. But the tidy alignment of averages masks the uncertainty which continues to characterize American agriculture in an unstable world. A policy "for all seasons" is required to cope with the intermittent periods of excess supply and excess demand that will characterize agriculture in the years ahead. The Agriculture and Consumer Protection Act of 1973 provides that the Secretary of Agriculture either can stabilize market prices through adjustment in stocks and set aside requirements or can allow market prices to vary widely within a relatively uncontrolled farm economy.

With farmers the principal beneficiaries of a price upswing in 1973 (personal income of farm people is at an all time high and on a par with that of nonfarm people), farmers are not enthusiastic about programs to reduce variations in farm prices and incomes. Yet higher cash costs to pay for land and other inputs inflated by the energy crisis and other factors make farmers vulnerable, financially, more than ever before to price and income fluctuations. But farmers see considerable protection from uncertainty through target prices and direct payments under the 1973 Act. Thus the principal beneficiaries of policies to manage reserves for greater price stability are consumers rather than farmers—although by 1976, the 1973 loan and target prices appear to be a modest level of security indeed for farmers.

A sample of urban consumers favors policies to manage reserves for price stability, but only if the government administers such policies efficiently. Apathy among consumers toward public programs to manage reserves appeared to be motivated by a current lack of confidence in government. To interpret this lack of support for policies to reduce price instability as a call for a free market would do considerable disservice to society and forego welfare gains outlined in this paper that are well within the reach of public policy.

This paper leaves several issues unresolved:

1. A policy to manage reserves efficiently must establish under what conditions stocks will be accumulated and released. At issue also is the proper size of stocks under various circumstances, who will hold them (private traders, farmers, CCC, or foreign countries), and who will pay carrying charges.

2. Can trade negotiations help to provide growth and stability to U. S. farm exports? Presumably, Congress in 1974 will pass the Trade Reform Act in preparation for the Nixon round of trade negotiations. The administration appears hopeful of improving access to international markets for U. S. agricultural commodities by insisting on simultaneous negotiation of reduced barriers to trade in industrial *and* agricultural commodities. Is there a sufficient base of analyses and data for such negotiations and is there reasonable probability of success? Commodity agreements have not been notably successful in stabilizing world markets. Are there other international institutional arrangements that might reduce the volatility of world trade as it impacts unfavorably on individual countries?

3. Will preeminent food and commercial agriculture policies continue to divert attention from rural poverty and rural development? The 1973 Act commendably separates programs aimed at problems of commercial farmers from those of low resource-low income farmers: It provides flexibility for dealing with instability problems of commercial agriculture but offers little to the small farmer. Neither does the inadequately funded Rural Development Act of 1972. And a Family Assistance Plan or wage-earnings supplement to aid the working poor suffers persistent neglect that is increasingly hard to view as benign.

4. Consumers express their sovereignty increasingly through the political process. Unfortunately, overreaction of the body politic toward price rises brings shortsighted policies of price controls and rationing. We make no brief that management of reserves is free of pitfalls, but alternatives such as price controls and rationing are even less appealing.

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Discussion: D. E. HATHAWAY, *The Ford Foundation*

For the sake of logic as well as contrast, I shall comment on the papers in the order they were presented, first treating each separately and then discussing them as a group.

Dr. Paarlberg is an "old pro" in the best sense of the word, both as an agricultural economist and as a policy adviser. And to use football parlance, which seems to be so well understood in Washington these days, he suggests that the current game plan for U. S. and world food policy will be a winning one. This is suggested despite the fact that use of this plan during the past year may have contributed to missing food prices by about 20 percentage points. This game plan was also in use when our defenses were successfully penetrated by some rookies in the world grain market and when our output offenses were slowed by new defenses of major input suppliers. Moreover continued reliance on the current game plan can be challenged on the grounds that the U. S. agricultural team, including the American farmers, does not seem to be responding to the old signals in the same way that it responded in the past.

First let us examine Paarlberg's assessment of the short-run situation. He says, "thus, in the 1974–75 marketing year, if weather conditions are normal or better, there should be a rebuilding of grain stocks throughout the world and a resulting decline of prices from the extraordinary levels reached in 1973." This is remarkably similar to the official forecasts which preceded the crop of 1973—a season in which we did have normal or better weather over most of the world. Could it be that even with average weather in 1974 the world food grain situation is as likely to worsen as it is to improve? I think so for these reasons. Much of European, Japanese, and North American food production is built on high energy technology which is heavily dependent on nitrogen fertilizer. So also, unfortunately, are the high yielding varieties which are key components of much of the Green Revolution. Shortages of and price increases on fertilizer and energy alone would, it seems to me, tend to cause yields to fall below trends rather than sustain them in the industrialized nations.

Further, it is my impression that uncertainties as to supplies and prices are causing grain farmers to respond somewhat differently than in the recent past. The new and very great uncertainty evolving from escalating feed prices has livestock producers reacting in what appears to be new and as yet unpredictable ways.

Turning to the developing nations, we have some disturbing estimates of the extent and effect of current fertilizer shortages on the output of grains in several major LDC's. The unofficial field reports we have were prepared before the recent round of petroleum prices occurred, which could easily double again the cost of fertilizer and the price of fuel to run irrigation pumps. Even so the reports forecast fertilizer-energy caused reductions in food grain production in several countries in Asia in 1974, even with good weather. Needed fertilizer, especially nitrogen and phosphate, is simply not available in adequate supplies.

In regard to the longer run projections, we are concerned with some of the inferences and assumptions which to me appear unrealistic in December 1973. First is the inference that existing technology is adequate to the taste. Paarlberg says, "in other words the developed countries have shown the way; the technological problem for the developing countries is how to adapt and apply *existing* technology [italics mine]." To my view it would be more accurate to say that for rice, at least presently, the technology does not exist that will significantly increase yields under rain-fed and upland conditions. Further, we must remind ourselves that the improved technology for irrigated rice is dependent upon fertilizer, pesticides, and water availability—all of which are heavily dependent upon fossil fuel.

Going further, Paarlberg states, "you may ask why we did not consider a pessimistic projection, based upon diminishing supplies of energy and natural resources, and a decline in the rate of economic growth . . . . We have not thought this set of conditions to have probability high enough, during the time span under consideration, to warrant its inclusion." In light of the events of the past several months and the official predictions of continued energy shortages, one wonders whether this component of the analysis can be so easily ignored.

To conclude my comments on Paarlberg's paper, it is my judgment that the only certainty for 1974 and 1985 is that there is and will be continuing uncertainty and quite likely substantial instability in world food supply, demand, and prices—unless some major changes are made in current U. S. and world policies and programs.

In discussing the paper by Drs. Mayer and Seevers, I again use the football analogy. Speaking of the past, they say, "these circumstances led to an environment in which policy decisions were fairly simple." The authors might be likened to a rookie quarterback who has just been hit from the blind side on three successive plays and concluded that people are playing rougher than they did in old days. But quarterbacks found the going a bit rough in some earlier ball games too. Policy making has not necessarily been simple, easy, and restful in the past; 1973 is not the first year when the United States government had to make basic decisions on both domestic and world food policy. One such decision was made during the Indian food crisis of 1966–67. Trade-offs between domestic prices, farm income, budget costs, hungry people, and commercial trade interests were all involved, just as they are now. Then as now it was understood that the entire food and fiber industry was closely interrelated, that decisions and major price changes in one sector would affect all others.

Turning from tone to substance, I believe Mayer and Seevers have correctly identified the effects of the perceptible shift in the supply price of livestock and the fact that the shift to a policy of no government-held stocks and our complete reliance upon private traders for exports leaves us in a new and highly vulnerable situation. What they did not say, however, is that the resulting economic pressures on food prices which will be built into the entire wage-price structure have cost the economy far more in 1973 and will continue to do so in 1974 and future years, than did the most expensive decade of our excess supplies and government-held stocks.

Why are we so late in making the necessary analysis? My own feeling is that the major problem lies with the failure of our policy makers in the Congress, leaders of Farm Organizations, and the Executive to consider what the domestic economic implications of a sharp increase in export demand would be. The surplus and unlimited capacity syndrome was taken for granted and still seems to dominate much of our policy analysis and formulation.

Much has been made of the Russian grain purchases, some 20 million tons in 1972–73. But India imported 38.8 million metric tons of food grains in the five years 1964 to 1968, and about half of it was in the two drought years 1966 and 1967. If large scale starvation anywhere in the world is now politically unacceptable, and I believe that to be the case, another severe drought on the subcontinent or elsewhere would have had the same shock effect as the Russian purchase. By reducing our publicly-controlled stocks to zero and making associated changes, we have designed a set of policies that opens the U. S. and the world economy to a series of shocks. As we have seen in the past year, the shocks can have severe and lasting consequences, especially, as Paarlberg points out, on the poorest of the poor.

In their discussion of supply policy, Seevers and Mayer point out, correctly to my view, that the supply-price of meats relative to feedstuffs began to shift in the late 1960's. Given this fact, which I think is explainable, we must be concerned about the stable feed prices if we are to avoid further destabilization of an industry undergoing fundamental structural change. To my view they are rightly questioning the adoption of a set of price support, stock, and export policies that has removed much of the stability of the livestock industry, resulting in an industry which now faces both unstable costs and unstable demand.

The football analogy can be continued as coaches Drs. Tweeten and Plaxico come on the field. Their paper with its tightly reasoned theory and specific coefficients is reminiscent of those beautiful diagrams that all coaches put on the blackboard, each designed to produce a touchdown if it all works according to the diagram. Yet in the real world not every play works, and I doubt that most of our supply coefficients and capacity estimates based on historical data will hold. For instance, they state that no sharply higher ratio of prices paid to prices received will be necessary to elicit greater supply response. If so, how does one explain the widening of feed-livestock price ratios going back to 1967, as cited by Mayer and Seevers?

As another example Tweeten and Plaxico hold that "domestic demand for farm output can be predicted with considerable accuracy." To which one could ask—what will be the unemployment effects of the energy crisis, how will it affect incomes in the developed economies and thus the demand for red meats and feed grains? Will the inability to drive long distances for outdoor recreation shift those discretionary expenditures to more home barbecues, or what?

Tweeten and Plaxico say that "lack of economic research on the response of exports to price and the widespread practice of assuming a zero price elasticity of export demand for farm products is indefensible." I would argue that in a world where decisions to import are as much political as economic, dependence upon elasticities derived from political decisions would be equally indefensible. Thus, I would heartily endorse their comment, "a policy for 'all seasons' is required to cope with the intermittent periods of excess supply and excess demand that will characterize agriculture in the years ahead."

I also agree with Tweeten and Plaxico that "it is easy to conceive numerous scenarios depicting future demand and supply of U. S. farm output in an unstable world. It is also apparent that no one scenario has much credence. Since we cannot predict the future very well, we must confront the issue of how to live with uncertainty." If they had started here and then discussed how to do that, we would all have been in their debt.

Their sophisticated theoretical discussions of economic theory and instability are appreciated, but who wins or loses in a ball game depends upon the ability to recognize errors and opportunities and to cover the former and exploit the latter. Hence to my view much more than the organization of another reserve stock policy, mentioned in each of the last two papers, is needed to deal with the uncertain future. A consistent and manageable policy of food aid and supply guarantees to major importers dependent upon us should also be included.

In conclusion, it seems fair to generalize that we do not have a food and fiber policy at the present time that will (1) produce economic stability at home, (2) guarantee our position as a major exporter, (3) permit us to meet emergencies abroad, and (4) protect farmers from potential losses if world markets collapse due to slower industrial growth or substantial increases in foreign supplies. It is sad that analysts both within and outside government have not pointed out that under many circumstances the Agriculture and Consumer Protection Act of 1973 fails to provide the protection our society needs. It does not protect against price instability, uncertainty, and associated economic problems at home or abroad—unless it is used as a part of a larger coordinated, consistent food policy which yet remains to be developed.

Discussion: HOWARD W. HJORT, *Washington, D. C.*

We have been assured that the world has the capacity to supply 1985 food and fiber requirements. Tweeten and Plaxico conclude, "our farming industry has sufficient production capacity to meet demands placed on it to 1985." The ERS grains study reviewed by Paarlberg indicates the U. S. has sufficient potential to satisfy 1985 *grain* demands, and that conclusion apparently is supported by the Iowa State University study to which he refers. According to the ERS study, between now and 1985 the LDC's will become more dependent upon the developed countries for their grain requirements, while the developed countries, except Japan, will become more self-sufficient.

The near term outlook is less clear, but the consensus seems to be that world food supplies will be large enough by the mid-1970's to meet current requirements fully and to permit some stock rebuilding. Paarlberg sees an early recovery in world agricultural production, relief from the current tight supply situation as early as 1974–75, a resumption of the upward trend in per capita food supply, and lower farm product prices. But he believes prices are unlikely to fall to the levels that prevailed two years ago. Tweeten and Plaxico imply farm prices for the grains by the mid-1970's will be at a level that, due to the rapid escalation in costs of production, would be no better and probably worse in terms of net income than those observed prior to the 1972 price surge.

For the decade ending with 1985, policy implications that flow from these studies are straightforward: since the world supply-demand trends of the future are expected to be similar to those of the past, the pre-1972 policies, adequately described by Mayer and Seevers, should with only minor modification again become appropriate. Export expansion efforts should be directed more to the LDC's, initially to those who produce crude oil, since according to the ERS study, the LDC's will become increasingly dependent upon developed countries for grain requirements. In general though, the policies and programs of the past would again be in style—acreage set-aside, import controls tightened or reimposed, and export and domestic demand expansion programs reinstated or accelerated.

Yet we are told that even if the outlook is for a return to a general world excess supply situation, we need, to use Tweeten and Plaxico's phrase, a "policy for all seasons." We have recently seen how quickly the world food supply-demand balance can shift from excess supply to excess demand, and therefore our policies must be sufficiently flexible to accommodate the unpredictable but expected swings in production that characterize world agriculture. The need for flexibility in our set of laws and policies becomes more evident and more crucial when the level of trade is high or food reserves (in the form of acres or commodities) are low.

Tweeten and Plaxico argue that current legislation provides adequate authority to adjust production and flexibility to protect the income of farmers but does not sufficiently protect the consumer. Mayer and Seevers express concern over our ability to protect consumers from large upward moves in food prices and over our prospects for rebuilding food reserves. Tweeten and Plaxico join a rapidly growing group in restating the case for food reserves, to protect consumers, not producers.

The general problem with a reserves policy is that the case for reserves is strongest when we are in a short supply position, and thus reserves cannot be accumulated. Once the supply position improves enough for reserves to be accumulated, the case for reserves seems much less persuasive. There also is a legal complication. Under current legislation the cost of farm programs rises rapidly as market prices move down toward the loan rates, and therefore budget directors will want to keep the market price above the loan—a tight supply policy is preferred. The budget director and those concerned over farm income can now support farm programs that withhold enough acreage from production to keep market prices at or above the guarantee price but for different reasons—to minimize farm program costs and to maximize farm income. So, unless the lawyers can be convinced the old CCC purchase authority can be used to accumulate reserves and policy makers can be convinced they should accumulate reserves, the prospects for doing so are not good, especially when the present policy position is to keep the government out of the grain business and let the farmers, traders, and final users hold reserves. Some of the grain reserve controlled by the government could have been held back last year; instead it was sold. Non-government interests may hold adequate food reserves when supplies are tight, but will not do so when supplies are in excess of current requirements.

So far we have been talking about policies that would be appropriate under general excess supply conditions with this basic situation reversed periodically due to an unexpected event such as the 1972 weather induced drop in world agricultural production. That, however, is not the situation we are in today.

As we have been told by Paarlberg, world food supplies remain tight. By the end of the current marketing year the Soviet Union (and possibly China) will be holding most of the world's grain reserves. Weather for the 1973–74 crops was above normal, and that may have saved the day or prolonged the agony. Even with record 1973–74 world grain crops, stocks held by the major exporters are again being reduced over the 1973–74 marketing year. While the odds currently may favor a stock buildup over the 1974–75 marketing year, it is not wise to bet all the chips that weather will be normal or above again next year. The world does not now have the food reserves they had to call upon in mid-1972 to overcome a drop in world agricultural production. A shortfall half or even one-third as large as in 1972 would be disastrous. It could have been this year—world grain reserves would have been too small to satisfy consumption requirements if the 1973–74 rice crop had been no larger than the 1972–73 crop. Another way of viewing the current situation is to note that from the time USDA spokesmen started saying world grain production would be approximately sufficient to meet consumption requirements and that export controls would not be imposed, USDA has increased their estimate of world grain production by more than 30 million metric tons and reduced the estimate of major exporters' grain stocks by 5 m.m. tons. It has been good luck, not good policy, that so far has kept us from having to impose export controls on grains, and the wheat supply-demand balance is still so close that efforts are being made to curb exports from the United States.

Events over the past 18 months have again reminded us that the supply-demand balance can determine policy, and policy can, in part, determine the supply-demand balance. Policies today are 180 degrees away from those of mid-1972. It seems to me the key question today is not what policies should be for the 1975–85 decade, but instead what are the current policies and how adequate are they, given the current situation and outlook for 1974, 1975, and 1976. The background papers do not take us very far toward an answer to these questions. I wish the ERS study would have focused on the three years centered on 1975 instead of 1985; on food and agriculture, instead of grains (excluding rice, the world's major food grain); and on the impact of the energy crisis. I don't expect ERS, or anyone, to be able to predict what is going to happen—that cannot be done—but the implications of alternative scenarios can and must be traced so that there is a realistic framework under which policies can be formulated. The analytic task is more difficult under present circumstances, but also more necessary, as has been convincingly argued by Mayer and Seevers.

Not to consider the energy crisis serious enough to be fully explored by ERS is unbelievable. Energy shortages and sharply higher energy prices may be of greater significance to world agriculture than was the 1972 world agricultural production shortfall. The sharp jump in the price of crude oil will reorder the economic growth rates of the countries of the world. Major crude oil exporters will experience rapid rates of economic growth while major importers will have lower growth rates. This reordering will have an impact on the demand for agricultural products. Japan, the major importer of U. S. agricultural products, will be affected by energy shortages and price rises to a greater degree than any other developed country, simply because they are so dependent upon others for their energy supply. Many developing countries are both petroleum and fertilizer importers. Higher petroleum and fertilizer prices place another unexpected drain on their foreign exchange reserves, which, together with possible fertilizer and even fuel shortages, threaten to slow agricultural and industrial progress. These considerations raise serious questions about the appropriateness of the assumptions employed in the ERS study and lead to scepticism about the conclusions.

While good analyses are a prerequisite to good policies, analyses alone do not insure good policy. As Mayer and Seevers have pointed out, the case for a change in policy has to be very strong before change takes place. The process of changing policies over the last 18 months from those appropriate prior to mid-1972 to those in tune with the current situation was by no means smooth.

Serious and costly errors were made beginning with the delay in terminating export subsidies on wheat and deciding to withhold too much land from production, then later relaxing the set-aside requirements, but too late to avoid paying more than necessary. These actions were followed by the decision to get the government out of the grain business; cut demand expansion activities; permit more imports; attempt to control food prices, but not feed prices; and embargo oilseeds and products.

In general these policy changes can best be characterized as too little, too late. The consequences were larger export subsidies, more farm program payments, a tighter squeeze on livestock producers profits, and higher food costs than necessary but greater farm income and a more favorable balance of trade than would have been the case had policies changed sooner. As has been mentioned by Paarlberg and Mayer and Seevers, the poor, both here and abroad, found themselves worse off.

The policy record of the past 18 months raises serious questions about the ability of an Administration to act in a timely manner in the future. The policy position now is to let price be the rationer of commodities in scarce supply—dollars are of higher priority than people. And even though we have been assured export controls will not be imposed, we of course know that is an untenable position if supplies become scarce enough.

We have learned that in this, as in any other country of the world, one's own are taken care of first if there is not enough to take care of all. Embargos were imposed, and they will be again if necessary, policy pronouncements notwithstanding.

In summary, we are in a food supply-demand situation where the unexpected could be an even greater shock than in 1972. The world's grain reserves are held by the centrally planned economies. No one knows which way the balance is going to tip—the unexpected cannot be forecast in point of time—and therefore it is essential to have analysts who know how to explore the consequences of what may happen as well as seek the most likely, and for those with responsibility for policy formulation to be flexible enough to change policies when the time is right. A review of the past 18 months does not lead to confidence on either count.

FACTOR PRODUCTIVITY IN AGRICULTURE

Chairman: T. D. WALLACE, NORTH CAROLINA STATE UNIVERSITY

A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution*

HANS P. BINSWANGER

THE USE of a cost function rather than a production function for estimating production parameters has several advantages:

1. It is not necessary to impose homogeneity of degree one on the production process to arrive at estimation equations. Cost functions are homogeneous in prices regardless of the homogeneity properties of the production function, because a doubling of all prices will double the costs but will not affect factor ratios.

2. In general, the estimation equations have prices as independent variables rather than factor quantities, which, at the firm or industry level, are not proper exogenous variables. Entrepreneurs make decisions on factor use according to exogenous prices, which makes the factor levels endogenous decision variables.

3. If a production function procedure is used to derive estimates of elasticities of substitution or of factor demand in the many-factor case, the matrix of estimates of the production function coefficients has to be inverted. This will inevitably exaggerate estimation errors. No inversion is necessary when a cost function is used.

4. In the special case of the Translog cost function [5], to which the method is applied, problems of neutral or non-neutral efficiency differences among observational units (firms or states in a cross-section; years in a time-series) or of neutral and non-neutral economies of scale can be handled conveniently.[1] Therefore, these problems will not result in biased estimates of the production parameters. As will be discussed, such differences can result from a variety of sources. Most methods of estimating production cannot handle this problem properly.

5. In the case of the Translog cost function (as well as the Translog production function), all estimation equations are linear in logarithms.

6. In production function estimation, high multicollinearity among the input variables often causes problems. Since there is usually little multicollinearity among factor prices, this problem does not arise in cost function estimation.

The plan of this paper is as follows. First, a derivation of the Allen partial elasticity of substitution in terms of the cross derivatives of the cost function is presented. Then the result is applied to the case of the Translog cost function and methods to avoid estimation biases caused by neutral and non-neutral efficiency differences are discussed. Finally the Translog method is used to derive estimates of elasticities of derived demand and of elasticities of substitution for the agricultural sector using U. S. cross-section data of states for the years 1949, 1954, 1959, and 1964.

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[1] A non-neutral efficiency difference in the Hicksian sense is one in which the isoquant does not shift inwards homothetically. The factor ratio does not stay constant at a constant factor price ratio. If the capital-labor ratio increases, the efficiency gain is labor-saving. This implies that the labor share declines at a constant factor price ratio. Efficiency gain biases can, therefore, be defined as follows:

$$B_i = \frac{\partial \alpha_i}{\partial t} \cdot \frac{1}{\alpha_i} \begin{matrix} < \\ = \\ > \end{matrix} 0 \rightarrow \text{Hicks} \begin{cases} \text{factor } i\text{-saving} \\ \text{factor } i\text{-neutral} \\ \text{factor } i\text{-using} \end{cases}$$

where factor prices are held constant and α_i is the cost share of factor i. This definition is more easily handled in the many-factors case than the usual definition in terms of marginal rates of substitution.

Partial Elasticities of Substitution in Terms of Cost Function Parameters

Corresponding to the following cost minimization problem

$$(1)\qquad \min C = \sum_{i=1}^{n} X_i P_i \qquad (i = 1, 2, \ldots, n)$$

subject to

$$(2)\qquad Y = f(X_1, X_2, \ldots, X_n)$$

(where X_i = inputs levels, P_i = factor prices, Y = output), there exists a dual minimum cost function,[2]

$$(3)\qquad C^* = g(Y, P_1, \ldots, P_n).$$

This function (also called factor price frontier) assigns to every combination of input prices the minimum cost corresponding to the cost minimizing input levels X^*_i. C^* is homogeneous of degree one in prices.

Shephard's lemma [6] holds for the cost function

$$(4)\qquad \frac{\partial C^*}{\partial P_r} = X_r.$$

Let f be the bordered Hessian matrix of (2) and $f_i = \partial Y/\partial X_i$ and $f_{ij} = \partial^2 Y/\partial X_i \partial X_j$. Partial elasticities of substitution are defined by Allen as

$$(5)\qquad \sigma_{kr} = \frac{\sum_{i=1}^{n} X_i f_i}{X_k X_r} (f^{-1})_{rk},$$

where $(f^{-1})_{rk}$ is the rkth element of f^{-1}. From (5) it is apparent that

$$(6)\qquad \sigma_{kr} = \sigma_{rk}.$$

If estimates of the coefficients of a particular functional form of (2) are available, the bordered Hessian can be computed, inverted, and the σ's found according to (5) for specific input levels.[3] The inversion of a matrix of estimates has, however, the tendency to blow up estimation errors to an unknown extent and, because inversion is a nonlinear transformation, econometric properties of $\hat{\sigma}_{kr}$ cannot be found even if such properties of the production function parameters are known.

In the case of the cost function, estimates of σ_{kr} can be obtained directly from the parameters of the function, because

$$(7)\qquad \sigma_{rk} = \frac{\sum_{i=1}^{n} P_i X_i}{X_k X_r} \frac{\partial^2 C^*}{\partial P_r \partial P_k}.$$

This was originally proved for homogeneous production functions in Uzawa [15]. A proof which does not rely on homogeneity is given here.

Proof: The first order conditions of the cost minimizing problem (1) and (2) are

$$(8)\qquad f(X_1, \ldots, X_n) - Y = 0$$

$$(9)\qquad P_i - \lambda f_i = 0 \qquad i = 1, \ldots, n.$$

Writing the total differential of the first order conditions and rearranging the terms in the following matrix form,

$$(10)\qquad \lambda \begin{bmatrix} 0 & f_1 & \cdots\cdots & f_n \\ f_1 & f_{11} & \cdots\cdots & f_{1n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ f_n & f_{n1} & \cdots\cdots & f_{nn} \end{bmatrix} \cdot \begin{bmatrix} d\lambda/\lambda \\ dX_1 \\ \cdot \\ \cdot \\ \cdot \\ dX_n \end{bmatrix} = \begin{bmatrix} \lambda dY \\ dP_1 \\ \cdot \\ \cdot \\ \cdot \\ dP_n \end{bmatrix}.$$

Solving for the vector of endogenous variables,

$$(11)\qquad \begin{bmatrix} d\ln\lambda \\ dX_1 \\ \vdots \\ \cdot \\ dX_n \end{bmatrix} = \frac{1}{\lambda} f^{-1} \begin{bmatrix} dY \\ dP_1 \\ \cdot \\ \cdot \\ \cdot \\ dP_n \end{bmatrix}.$$

This implies

$$(12)\qquad \frac{\partial X_r}{\partial P_k} = \frac{1}{\lambda} (f^{-1})_{rk}.$$

Substituting from (10) into (5) and substituting $f_i = \frac{P_i}{\lambda}$ from (9),

$$(13)\qquad \sigma_{kr} = \frac{\sum_i X_i f_i}{X_k X_r} \lambda \frac{\partial X_r}{\partial P_k} = \frac{\sum_i X_i P_i}{X_k X_r} \frac{\partial X_r}{\partial P_k}.$$

Taking the derivative of (4) with respect to P_k,

$$(14)\qquad \frac{\partial^2 C^*}{\partial P_r \partial P_k} = \frac{\partial X_r}{\partial P_k}.$$

Combining (13) and (14) and (6),

$$\sigma_{kr} = \sigma_{rk} = \frac{\sum X_i P_i}{X_k X_r} \frac{\partial^2 C^*}{\partial P_r \partial P_k} \qquad \text{Q.E.D.}$$

Multiplying and dividing the righthand side of

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[2] While C of (1) is the cost of production under any feasible factor combination, C^* refers to the cost of production when the cost minimizing input combination is used. Since the optimal input combination is a function of the factor prices, the minimum cost is also.

[3] See Berndt and Christensen [1] for an example.

(13) by $\frac{P_k}{X_r}$,

$$\sigma_{kr} = \sigma_{rk} = \frac{\eta_{rk}}{\alpha_k}, \tag{15}$$

where $\eta_{rk} = \frac{\partial X_r}{\partial P_k}\frac{P_k}{X_r}$ and $\alpha_k = \frac{X_k P_k}{\Sigma X_i P_i}$ is the of factor k in total costs. If the parameters of specific functional form of a cost function have been estimated, (7) can be used to derive elasticities of substitution for given factor levels and total costs.[4]

The Translog Case

The Translog cost function is particularly useful in this context. It is written as a logarithmic Taylor series expansion to the second term of a twice differentiable analytic cost function around variable levels of 1, (i.e., $\ln Y = 0$, $\ln P_i = 0$, $i = 1, \ldots, n$). Rewrite (3) in natural logarithms:

$$\ln C^* = f(\ln Y, \ln P_1, \ldots \ln P_n). \tag{16}$$

Denote the first and second order derivatives at $\ln(\cdot) = 0$ as follows:

(17)

$$\ln C^* \bigg|_0 = \nu_o; \quad \frac{\partial \ln C^*}{\partial \ln Y}\bigg|_0 = \nu_y; \quad \frac{\partial \ln C^*}{\partial \ln P_i}\bigg|_0 = \nu_i;$$

$$\frac{\partial^2 \ln C^*}{\partial \ln P_i \, \partial \ln P_j}\bigg|_0 = \gamma_{ij}; \quad \frac{\partial^2 \ln C^*}{\partial \ln P_i \, \partial \ln Y}\bigg|_0 = \gamma_{iY}$$

The equality of the cross derivatives in (17) implies the symmetry constraint

$$\gamma_{ij} = \gamma_{ji}. \tag{18}$$

Then the Taylor series expansion is as follows:

$$\begin{aligned} \ln C^* = {} & \nu_o + \nu_y \ln Y + \sum_i \nu_i \ln P_i \\ & + 1/2 \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j \\ & + \sum_i \gamma_{iy} \ln P_i \ln Y \\ & + \text{remainder}. \end{aligned} \tag{19}$$

This function is an approximation of an arbitrary analytic function.[5], [6] It is a functional form in its own right if the remainder is neglected and if we assume all derivatives and cross-derivatives to be constant. This latter constraint is imposed if the parameters are estimated in regression equations.

Homogeneity in prices is defined as follows: $\lambda g(Y, P_1, \ldots, P_n) = g(Y, \lambda P_1, \ldots, \lambda P_n)$. It implies

(20)

$$\sum_i \nu_i = 1; \qquad \sum_i \gamma_{ij} = 0; \qquad \sum_j \gamma_{ij} = 0.$$

Homogeneity of degree one in prices does not impose homogeneity of degree one of the production function in inputs. Almost no constraints are imposed on elasticities of substitution or of factor demand, which makes the function more general than other functional forms currently in use [5].

The function can be estimated directly or in its first derivatives which, by Shepard's lemma (4), are factor shares:

$$\begin{aligned} \frac{\partial \ln C^*}{\partial \ln P_i} = \alpha_1 = \nu_i + \sum_j \gamma_{ij} \ln P_j & \\ + \gamma_{iy} \ln Y \quad (i = 1, \ldots, n). & \end{aligned} \tag{21}$$

Both sets of estimation equations are linear in logarithms and have proper exogenous variables on the right hand side if the analysis pertains to firms or an industry.[7]

The γ_{ij} parameters have little economic meaning of their own. We will prove that they are related to variable elasticities of substitution and of factor demand as follows:

(22)

$$\sigma_{ij} = \frac{1}{\alpha_i \alpha_j} \gamma_{ij} + 1 \qquad \text{for all } i, j;\ i \neq j$$

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[4] Also, if η_{kr} had been estimated in a demand for factors equation, one can compute σ_{rk} from (13). This may be particularly useful in the two-factors case since then the own elasticity of demand can be used. Because of the homogeneity of degree one of C^*, $\eta_{11} + \eta_{12} = 0$, and $\eta_{12} = -\eta_{11}$ can be substituted into (13).

[5] The first power terms of (19) represent a Cobb-Douglas cost function. If all γ_{ij} and γ_{iy} parameters were zero, the production function would be Cobb-Douglas as well, because the production function of a Cobb-Douglas cost function is Cobb-Douglas and vice versa [10].

[6] By a similar expansion of a production function the Translog production function is found.

$$\ln Y = \omega_o + \sum_i \omega_i \ln X_i + 1/2 \sum_i \sum_j \tau_{ij} \ln X_i \ln X_j.$$

[7] In the case of the Translog production function the estimation equations are similar but with factor quantities on the right-hand side. For the decision-making firm these are endogenous.

(23)
$$\sigma_{ii} = \frac{1}{\alpha^2_i}(\gamma_{ii} + \alpha^2_i - \alpha_i) \qquad \text{for all } i$$

(24)
$$\eta_{ij} = \frac{\gamma_{ij}}{\alpha_i} + \alpha_j \qquad \text{for all } i, j;\ i \neq j$$

$$(25)\quad \eta_{ii} = \frac{\gamma_{ii}}{\alpha_i} + \alpha_i - 1 \qquad \text{for all i.}$$

Proof:

(26)
$$\gamma_{ij} = \frac{\partial^2 \ln C^*}{\partial \ln P_i \, \partial \ln P_j} = P_j \frac{\partial}{\partial P_j}\left(\frac{\partial C^*}{\partial P_i}\frac{P_i}{C^*}\right)$$
$$= P_j\left(\frac{\partial^2 C^*}{\partial P_i \, \partial P_j}\frac{P_i}{C^*} - \frac{P_i}{(C^*)^2}\frac{\partial C^*}{\partial P_i}\frac{\partial C^*}{\partial P_j}\right).$$

Substituting $\frac{\partial C^*}{\partial P_k} = X_k$ from (4):

$$\gamma_{ij} = \frac{P_i P_j}{C^*}\frac{\partial^2 C}{\partial P_i \, \partial P_j} - \frac{P_i P_j}{(C^*)^2} X_i X_j.$$

Therefore,

$$(27)\qquad \frac{\partial^2 C^*}{\partial P_i \, \partial P_j} = \frac{C^*}{P_i P_j}(\gamma_{ij} + \alpha_i \alpha_j).$$

Substituting (27) into (7):

$$\sigma_{ij} = \frac{\Sigma P_i X_i \cdot C^*}{P_i X_i P_j X_j}(\gamma_{ij} + \alpha_i \alpha_j)$$
$$= \frac{\gamma_{ij}}{\alpha_i \alpha_j} + 1 \qquad \text{Q.E.D.}$$

(24) follows from (15). The proof of (23) is similar, except that in (26) $\partial P_i / \partial P_i = 1$ which accounts for $-\alpha_i$ in equation (23). (25) follows again from (15).

If the γ_{ij} parameters have been estimated with equations (19) and/or (21), and if the factor shares are known, all elasticities can be estimated. Since $\hat{\sigma}_{ij}$ and $\hat{\eta}_{ij}$ are linear transformations of the γ_{ij} parameters whose econometric properties are known, the econometric properties of the elasticities are known as well. No matrix of estimates has to be inverted.[8]

Treatment of Neutral and Non-neutral Efficiency Differences

If efficiency differences exist among the observational units (states or firms in cross-sections, years in time-series), the specification of the estimation equations must take into account the problem in order to avoid bias in estimation.

It is best to distinguish two kinds of efficiency differences:

1. Differences which can be functionally related to a variable such as output (scale effects), or a technical change index, or time (as a proxy for technical change), or education and management (the left-out variables problem).

2. Differences among cross-sectional units which cannot be functionally related to a variable and which arise from past differences in technical change. If the cross-sectional units have had a different past history of technical change, they are no longer on the same isoquant. This is likely to happen in many cross-sections.

The first case is easily handled. Let the variable Y in (19) and (21) stand for any of the variables which cause the neutral and non-neutral efficiency differences (output, time, technical change index, or education). Then (19) and (21) are immediately correctly specified, provided that the variable Y changes efficiency at constant logarithmic rates, and that data on the variable Y are available. As an example, if time-series data are used and technical change causes the efficiency differences at constant rates over time, let Y stand for time. The coefficient γ_Y will then be an estimator of the rate of technical change, and the coefficients γ_{iY} will be estimators of the rates of bias. If all γ_{iY} were zero, time alone would not affect the factor shares (equation 21). This is the definition of neutrality in footnote 1. If γ_{iY} was greater than zero, the share of factor i would rise at constant factor prices at the logarithmic rate γ_{iY}. This would be factor i-using technical change.

If a variable for which no data are available causes efficiency differences, the γ_{ij} can still be estimated in an unbiased way, provided the left-out variable affects efficiency neutrally. In that case, all the γ_{iY} parameters are zero and (21) is still properly specified without data on the variable Y. But because γ_Y is not zero, (19) is no longer correctly specified. Therefore, the γ_{ij} parameters have to be estimated in (21) alone.[9]

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[8] For estimating marginal products the cost function has the same disadvantage as the production function in estimating elasticities of substitution. Estimates of its bordered Hessian have to be inverted. Since the Translog cost function and the Translog production function use the same basic data (input quantities and prices), it would be preferable to estimate the σ_{ij} and η_{ij} using the former function while using the latter one for the marginal products.

[9] Including education, etc., in a Cobb-Douglas production function assumes that these variables affect effi-

In the next section scale effects will be assumed to be neutral. Output is, therefore, not included as a variable in (21). On the other hand, technical change over time is assumed to be non-neutral, and time is included as a variable (Y thus standing for time).

Problem (2) of efficiency differences among cross-sectional units can be handled in the same way as the left-out variables problems above, provided the efficiency differences are neutral. The proper variable would be an efficiency index of the cross-sectional units which is generally unknown. However, if the efficiency differences are non-neutral due to biased technical change in different directions in previous periods, it would be necessary to know the efficiency index and include it as a variable in (21). If the index is not available, but the cross-sectional units can be grouped into regions, within which no non-neutral differences exist, regional dummies in equation (21) will again insure unbiased estimates of the parameters of the cost function, because they allow the regions to have differing shares at equal factor prices. This again precludes simultaneous estimation of (17) and (19). The discussion of this entire section applies equally to the Translog production function.

Estimation, Data, and Conclusions

The cost function was estimated with state data for the United States. Four sets of cross-sectional data were obtained for 39 states or groups of states. The cross-sections were derived from census data and other agricultural statistics for the years 1949, 1954, 1959, and 1964. The combination of cross-sections over time poses problems which are discussed below. In general, Griliches's [9] definitions of factors were used. He distinguishes the following five factors: land, labor, machinery, fertilizer, and all others.[10] For all data pooled the following model was fitted:

(28)

$$\alpha_{ikt} = \nu_i + \sum_j \gamma_{ij} \ln P_{jkt} + \gamma_{it} \ln t + \sum_{r=1}^{4} \delta_{ir}\, d_r + \epsilon_{ikt} \qquad i = 1, \ldots, n-1, \quad j = 1, \ldots, n,$$

where i and j stand for factors of production, k for states, t for time, r for groups of states, and

$$d_r = \begin{cases} 1 \text{ if } k \in r \\ 0 \text{ if } k \notin r. \end{cases}$$

δ_r is the coefficient of the non-neutral efficiency difference between group r and group 5 (Western States). One share equation has to be dropped from the model because only $n - 1$ equations are linearly independent due to the homogeneity constraint (20). In this form the model allows for neutral efficiency differences of any kind among states, non-neutral efficiency differences among groups of states, and non-neutral efficiency differences over time.

Within each of the four cross-sections (time period), the error terms of the $n - 1$ estimation equations are not independent, since for each state the same variables which might affect the shares in addition to the prices were left out of the model. If restrictions across equations ($\gamma_{ij} = \gamma_{ji}$) are imposed, OLS estimators are no longer efficient despite the fact that all equations contain the same explanatory variables on the right-hand side [13]. Therefore, the seemingly unrelated regression problem applies, and restricted generalized least squares (RGLS) have to be applied to all equations simultaneously [13, Ch. 9].

If all four cross-sections are pooled, there is an additional problem of error interdependence over time. The correct way of handling both problems would be to specify an equation for each share in each year, then test and impose the symmetry and homogeneity constraints and the constraints that the γ_{ij} parameters are constant over time. This exceeded the capacity of the program used.[11] The correct procedure would also have required that one impose constraints of equality of the auto-correlation coefficients over time on the estimated variance covariance matrix, which was not possible with TTLS. The following procedure was therefore adopted. To search for an exact specification, RGLS regressions were applied to the data of each cross-section separately to avoid any biases in the tests used for this purpose.[12] Once the decision was

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ciency of the other factors neutrally because all elasticities of substitution are 1.

[10] The data are discussed in detail in the Appendix.

[11] The Computer Program used was that of the Triangle Universities Computing Center (TTLS) [14].

[12] No *a priori* information is available to decide which equation to drop and whether or not to include regional dummies. To make these decisions, I was looking for the specification in which the imposition of the symmetry constraint $\gamma_{ij} = \gamma_{ji}$ and the homogeneity constraint $\sum_j \gamma_{ij} = 0$ led to the smallest weighted F-ratio according to the test static in equation (3.6) of Theil [13, p. 314]. Since both of these constraints are "true" constraints, they can be used in this way to eliminate

Table 1. Restricted estimates of the coefficients of the Translog cost function and t-Ratios[a, b]

Factor	Price of land	Price of labor	Machinery price	Fertilizer price	Price of other[c]	Year	Intercept	MN	GF	SE	GS[d]
	Independent Variables										
Share of Land	.07747	—.03613	.00478	.01066	—.05678	.00847	.2603	—.1021	—.0394	—.1073	—.0577
	(6.02)	(3.25)	(.47)	(2.14)		(1.47)	(9.96)	(10.2)	(4.1)	(8.9)	(4.7)
Share of labor		—.06367	—.00661	—.02805	.13446	—.05482	.5218	.0194	—.0016	.0169	.0246
		(3.67)	(.59)	(4.97)		(9.08)	(14.91)	(1.63)	(.15)	(1.09)	(1.63)
Share of machinery			—.03485	—.03877	.04545	.02498	.0926	—.0033	.0369	—.0186	.0072
			(1.31)	(.97)		(4.66)	(3.46)	(.41)	(5.08)	(1.86)	(.73)
	Symmetric										
Share of fertilizer				.00068	.02548	.00178	.0745	.0104	—.0041	.0370	—.0025
				(.12)		(.63)	(5.6)	(2.5)	(1.10)	(7.24)	(.49)
Share of other					—.14861						

Source: See Appendix.

[a] Restrictions imposed: $\gamma_{ij} = \gamma_{ji}$ and $\sum_{j=1}^{n} \gamma_{ij} = 0$ for all i, j.

[b] Critical values with 578 degrees of freedom are $t_{.05} = 1.96$ and $t_{.01} = 1.65$. t-ratios may be overstated due to error interdependence over time.

[c] Implied estimates computed using the homogeneity constraint.

[d] MN, GF, SE, and GS are dummies for Mixed Northern agriculture, Grain Farming states, Southeast, and Gulf States, respectively. The intercept stands for Western States, and the coefficients of MN, GR, SE, GS are deviations from this intercept.

made to use a specification including equations for land, labor, machinery, and fertilizer, with regional dummies in all equations, all four cross-sections were pooled and the symmetry and homogeneity constraints imposed in the restricted generalized least squares estimation of all four equations simultaneously using equation (28). Since the error interdependence over time is neglected, the reported t-ratios will be overstated to some extent,[13] but the estimators are still unbiased.

The results of the regressions are reported in Table 1. The OLS single equation R^2 of the four shares equations with homogeneity imposed on the data are not very high:[14] land 0.68, labor 0.75, machinery 0.45, and fertilizer 0.75.

From Table 1 the following conclusions emerge:

1. Out of the 10 γ_{ij} estimates, only 5 are statistically significant. This is not a "bad" result because $\gamma_{ij} = 0$ implies that the elasticity of substitution is equal to the Cobb-Douglas value of 1. Note, however, that when the Cobb-Douglas constraint $\gamma_{ij} = 0$ for all i, j was tested in various single cross-section models, it was always rejected. Therefore, the conclusion is that the Cobb-Douglas form is not an appropriate production or cost function specification.

2. The coefficient of the time variable is significant at the .05 level in the labor and machinery equations. This means that, at constant factor prices, the factor shares would have changed, which implies non-neutral technical change during the period 1949 to 1964. The coefficient for time in the labor equation is —.0548. Hence, technical change was labor-saving. On the other hand the positive coefficient of time in the machinery equation (+.0250) implies machinery-using technical change. This is consistent with the findings of Lianos [12] and my own findings [4].

3. Six of the regional dummies are significant. At equal factor prices the shares would not be equal among the groups of states. The coefficients of the dummies in the land equation of all four regions is negative. This implies that the technology in all regions is land-saving relative to the technology used in the Western states—Washington, Oregon, and California. The significant positive coefficients in the fertilizer equation

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some specifications, although several specifications might satisfy the constraints. A specification in which "other" inputs are excluded and dummies added to all equations satisfied this criterion best for the four cross-sections. homogeneity of degree one of C^*, $\eta_{11} + \eta_{12} = 0$, and sections. Symmetry was only rejected in the cross-section of 1964 with an F-ratio of 4.19 (Critical $F_{.05} = 2.17$).

[13] Despite the 5-year interval between the cross-sections, error interdependence over time was still quite large. Correlation coefficients of the OLS errors of individual share equations between the years 1949 and 1964 were between .62 and .87. To check whether the neglect of this interdependence among cross-sections had a large impact on the values of the γ_{ij} estimates, I compared the estimates of the pooled cross-sections with the simple average of the estimates obtained in the four cross-sections individually. The differences of the estimates were small.

[14] The residuals of these equations are used to estimate the variance-covariance matrix for the GLS regressions.

Table 2. Factor demand and cross demand elasticities implied in the estimated γ_{ij} and their value in the Cobb-Douglas case[a, b]

	Land	Labor	Machinery	Fertilizer	Other
Estimated Translog values[c]					
Land	—.3356	.0613	.1792	.1062	—.0112
	(.09)	(.07)	(.07)	(.03)	
Labor	.0308	—.9109	.1256	—.0577	.8122
	(.04)	(.06)	(.04)	(.02)	
Machinery	.1833	.2560	—1.0886	—.0239	.6733
	(.07)	(.08)	(.18)	(.06)	
Fertilizer	.4506	—.4878	—.0991	—.9452	1.0815
	(.10)	(.20)	(.30)	(.16)	
Other	—.0046	.6690	.2720	.1053	—1.0417
Cobb-Douglas values for comparison[d]					
Land	—.8491	.3008	.1475	.0356	.3652
Labor	.1509	—.6992	.1475	.0356	.3652
Machinery	.1509	.3008	—.8525	.0356	.3652
Fertilizer	.1509	.3008	.1475	—.9644	.3652
Other	.1509	.3008	.1475	.0356	—.6348

Source: See Appendix.

[a] Standard errors in parentheses: $SE(\eta_{ii}) = SE(\gamma_{ii})/\alpha_i$.

[b] Each element in the table is the elasticity of demand for the input in the row after a price change of the input in the column. These elasticities are not symmetric.

[c] The shares used are the same as for the Cobb-Douglas η_{ij}.

[d] $\eta_{ij} = \alpha_j$; $\eta_{ii} = \alpha_i - 1$.

Table 3. Estimates of the partial elasticities of substitution[a, b]

	Land	Labor	Machinery	Fertilizer	Other
Land	—2.225	.204	1.215	2.987	—.031
	(.57)	(.24)	(.46)	(.93)	
Labor		—3.028	.851	—1.622	2.224
		(.19)	(.25)	(.53)	
Machinery			—7.379	—.672	1.844
		Symmetric	(1.22)	(1.71)	
Fertilizer				—26.573	2.961
				(4.61)	
Other					—2.852

[a] Standard errors $SE(\sigma_{ij}) = SE(\gamma_{ij})/\alpha_i\alpha_j$ in parentheses.

[b] The elasticities of substitution are symmetric. The own elasticity of substitution has little economic meaning except that it has to obey the constraint $\sum_j \alpha_j \cdot \sigma_{ij} = 0$.

of the dummies for the Mixed Northern states and the South Eastern states would indicate that these regions have a more fertilizer-using technology than the Western states.[15]

The γ_{ij} parameters have little economic meaning. They are best evaluated by the values which they imply for elasticities of factor demand and elasticities of substitution. The values are computed for the simple average of factor shares for all 39 states between 1949 and 1964. In Table 2 the elasticities are compared with what they would be at equal factor shares in the Cobb-Douglas case ($\gamma_{ij} = 0$).[16]

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[15] Not too much should be made of these regional differences because they may be due to different product mixes rather than to true technological differences in each production. If they reflect product mix differences, the dummies will at least correct for possible biases due to these differences.

[16] The elasticities were also computed using aggregate factor shares reported in Binswanger [4] for the years 1912, 1952, 1964, and 1969. While differences exist with the values reported here, they are not large. The main advantage of using a variable elasticity of substitution function rather than a CES framework is not that the elasticities vary widely for observed values of shares,

Tables 2 and 3 imply the following conclusions:

4. All own elasticities of factor demand have the correct sign. Land demand seems to be very inelastic. In empirical work with Cobb-Douglas production functions the coefficient of land is usually between 0.15 and 0.40. According to equation (25) with $\gamma_{ij} = 0$ (the Cobb-Douglas constraint), these values imply land demand elasticities of —0.85 to —0.60, which is substantially higher than the elasticity found with the Translog cost function.

The values of the other own demand elasticities are close to one and, except for fertilizer, higher than they would be in the Cobb-Douglas case. The fertilizer demand is substantially less elastic than Griliches's [8] estimate of —2.0.[17]

5. Elasticities of substitution and cross-elasticities of demand are positive for substitutes and negative for complements. These relationships are easier to evaluate by looking at the elasticities of substitution in Table 3 than the cross-elasticities of demand because the latter reflect the relative importance (share) of a factor while the former do not. Complementarity seems to exist between the labor-fertilizer pair, the machinery-fertilizer pair, and the land-other inputs pair. But only the complementarity of fertilizer and labor is significant. This is a noteworthy result. If this was generally true for all countries, it could have an important implication. Less developed countries with unemployed labor might find an advantage in pushing fertilizer use.

The best substitutes are land and fertilizer, which was expected. It was a surprise, however, to find that machinery is a better substitute for land than for labor (although the machinery-labor elasticity falls within one standard deviation of the land-labor elasticity, so that there is no statistical difference). Even if the machinery-land elasticity was over-estimated to some extent, the finding should cast doubt on the notion that one can dichotomize agricultural technology in mechanical technology which acts exclusively as a labor substitute and biological technology which acts exclusively as a land substitute.[18] The small elasticity of substitution between land and labor was expected. It is also clear that the agricultural production function is not separable between any input groups. Such a separability implies that the elasticities of substitution between the factors in the separable group and all other factors are identical. This is clearly not the case for any factor group [2].

Overall the result seems to be reasonable and shows that cost functions, in general, and the Translog cost function, in particular, lead to valuable methods for estimation of production parameters.

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but that this format does not constrain all elasticities of substitution to be equal [15].

[17] These estimates are not necessarily in conflict. Griliches estimates a long-run elasticity in a time-series. This implies that, if there is an induced fertilizer-using innovation due to a fall in the price of fertilizer, his price response picks up part of the adjustment due to the technical change. This is what happened in U. S. agriculture [4]. Since the inclusion of the time variable in our regression equations picks up the influence of technical change, the estimates presented here are net of any technical change influence.

[18] This idea is put forward in Hayami and Ruttan [11]. It stands up well with respect to labor and fertilizer, which are complements. But the high substitutability between machinery and land is inconsistent with that notion.

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APPENDIX

Variable Construction and Data Sources

For 39 states or groups of states, aggregate input quantity data and expenditure data were derived.

Quantity data

Except for "other" inputs, the quantity data were taken from Fishelson [7], who used Griliches's data with some changes. For a detailed discussion of labor, land, and machinery, see Griliches [9, pp. 966 and 973] or Binswanger [3].

Fishelson's discussion of the construction of the land variable is reproduced here:

> In the U. S. Census of Agriculture (U. S. Bureau of the Census, 1952, 1956, 1962 and 1966), the average value of land and buildings per farm in each state was reported. However, the land value represented not only the value of land to agricultural production but also included the site value of land. The value of buildings included both farm structures and dwellings. Hence, census data on value of land and buildings were inadequate for the purposes of this study. To measure land by the number of acres per farm (giving each acre a value of one) is also inadequate because of the diversity of soil quality, fertility and uses.
>
> In this study the weighting procedure for measuring land value was based on a study by Hoover. The value of each acre in each state at each cross-section was measured by its 1940 price relative to that of an acre of pasture in the corresponding state. The value of an acre of pasture in each state in 1940 was calculated by dividing the total value of land in 1940 by the number of pasture equivalent units of the land in 1940. This value of an acre of pasture was kept constant over time. . . . The use of this method provided a measure of the stock of land in constant prices. According to this method, changes in the stock of land occurred only because of changes in the number of acres or their use. The stock of land was unaffected by changes in prices of agricultural products, site effects, or government programs. [7, pp. 79–80].

The only change which was made in the quantity data taken from Fishelson [7] was that, whenever quantities per farm were used, the farm number was taken from various issues of the Census of Agriculture (U. S. Department of Commerce, 1950, 1954, 1959, 1964), rather than from *Farm Labor* (USDA, 1945–1972).

Since expenditure data corresponding to Fishelson's quantity data could not be constructed for "other inputs," new quantity data were defined as follows: The quantity of other inputs is the sum of the explicit and implicit annual expenditures on all other material inputs used in production. The explicit expenditures were the cash expenditures on purchases of livestock, poultry, feed, seeds, plants, and bulbs, operation and repairs of farm structures, and other miscellaneous costs. The implicit expenditures were 8 percent interest on livestock and crop inventories, depreciation (4.2 percent), and interest (5 percent) on the value of farm structures, and the share of real estate taxes falling on buildings. Each of the expenditures was separately deflated to its 1949 price level to arrive at a quantity measurement (for taxes the agricultural output price index was used).

Expenditures and factor shares

The expenditure variables were defined, as far as possible, to correspond to the quantity variables. Expenditure shares were obtained by dividing the expenditures of each factor by the sum of the expenditures.

Expenditures on land are simply 6 percent of the value of land plus the share of real estate taxes falling on land.

Expenditures for labor are the number of man days of labor from Fishelson [7] multiplied by a daily wage rate without room and board (*Farm Labor*, 1945–1972). This assumes that the opportunity cost of farm operators is the wage rate which they could earn as workers on other farms.

Expenditures for machinery are assumed to be 15 percent of the value of farm machinery and equipment for interest and depreciation plus the current expenditures for operation and repair of machinery and equipment.

Fertilizer expenditures are directly reported by the USDA.

Other expenditures were computed exactly as the quantity of other inputs, except that the individual items were not deflated. Aggregate expenditures estimated in this way had a tendency to exceed aggregate income by up to 10 percent.

Prices were taken to be the expenditures divided by the quantities. They were then deflated to the 1949 price level using the U. S. agricultural output price index. Note that this procedure implies that the price of other inputs is equal to one for all states in the year 1949. Appendix Table 1 lists all the data sources.

Appendix Table 1. Data sources

Variables	Source
Farm income, change in inventories, rental value of dwellings, all explicit current operating expenditures	*Farm Income Situation,* July supplement, USDA (1954–1972)
Annual average daily wage rate without board or room	Various issues of *Farm Labor,* USDA (1945–1972)
Farm number	Various issues of *Census of Agriculture,* U. S. Department of Commerce (1950, 1954, 1959, 1964)
Input and output price indexes	Various issues of *Agricultural Statistics,* USDA (1936–1972)
Repairs and operation of farm dwellings and service structures, depreciation and dwellings, service buildings, motor vehicles, other machinery and equipment, value of farm machinery and equipment, value of crop inventories	USDA, unpublished

The "Green Revolution" in Recent Development Experience

ROBERT EVENSON

THE TERM "green revolution" is now familiar to everyone with more than a passing interest in economic development. The Mexican wheat varieties and the IRRI rice varieties were accorded miracle status by the media as they were rapidly adopted in a number of Asian and African countries after 1965. Their initial promise sparked food self-sufficiency drives in several countries. By 1970 the adoption of these improved, high yielding varieties was credited with providing a realistic basis for sustained productivity gains in LDC agriculture. That promise has turned out to be short-lived, however. The optimism that existed three years ago has all but vanished. The adoption of high yielding varieties has fallen short of expectations, and the abnormally poor weather of the past two years has produced serious food shortages throughout the world.

The green revolution "episode" has been subject to numerous evaluations (Willet [8], Barker [1]). Most prior evaluations have made comparative assessments of production and resource utilization between high yielding rice or wheat varietal technology and local or native varietal technology. Dozens of studies have reported very significant cost advantages for the high yielding varietal technology. These studies, however, are all quite local in nature, and in almost all cases, are based on farm data from regions of early adoption of the high yielding varieties. They cannot be used to assess the relative advantage of high yielding varieties over the entire rice or wheat producing regions of the countries where they have been adopted.

This paper develops a methodology for assessing the relative advantage of the high yielding varieties in large producing regions and reports estimates of their contribution to aggregate production in Asia and North Africa. A simple specification based on the supposition that real productivity gains in the region were exclusively associated with the adoption of high yielding varieties is first developed. It is rejected in favor of a somewhat richer specification which explicitly considers the contribution of indigenous or national agricultural research activities to productivity gains.

The Setting for the Green Revolution Episode

A brief review of the historical and institutional setting in which the rapid and geographically widespread diffusion of a few wheat and rice varieties took place will be useful. We will not dwell specifically on the discovery of those varieties. That story has been told and retold in many places. Serious scholars know that the discovery of the improved wheats was the culmination of years of dedicated and competent effort by a number of agricultural scientists. The scientific knowledge which provided the foundation for these discoveries had been developed over many years. Similarly, the new rices were developed from a scientific base, years in the making. The discoveries themselves were not mysterious, not miraculous, and for that matter, not really extraordinary.[1]

What was extraordinary about the episode was that very little organized activity directed toward the discovery of improved varieties of foodgrains in the tropical and subtropical climate zones was being undertaken in the 1950's. As a consequence, the discoveries, particularly the wheat varieties from the Rockefeller Foundation program in Mexico, were diffused over very wide geographic areas. Such widespread diffusion would have been very unlikely in the temperate and steppe climate zones where dozens of first-rate discovery institutions have been in place for a number of years. The existence of a reasonably and efficiently organized system of discovery institutions, in which each major research center is oriented toward the discovery of technology suited to the soil, climate, and economic characteristics facing its clientele, effectively prevents widespread direct diffusion of technology. Green revolutions, in the popular sense of the term, would not occur in a modern system of scientific and technology discovery institutions.

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[1] This is not to denigrate the contributions of a number of the dedicated scientists involved. The point here is that when compared to other discoveries made by agricultural scientists, they were not unusual.

The poorly organized and understaffed research systems of almost the entire less developed world in the 1950's did provide the ideal setting for a green revolution, just as the organization (or lack of it) of sugarcane research in the 1920's and 1930's led to the widespread diffusion of the Indian and Javanese interspecific sugarcane hybrids of that period.[2] Green revolutions, while of great importance, do provide strong evidence that serious underinvestment in regional location-specific technology discovery prevails. Even under conditions in which relatively little competing discovery is being undertaken, however, soil and climate factors will limit the geographic scope of the superiority of new varieties.

The Simple Aggregate Evidence

Estimation of the contribution of the green revolution high yielding varieties could, with adequate data, be undertaken on a country-by-country basis. A productivity relationship might be specified in which changes in wheat and rice output are related to changes in the utilization of land, fertilizer, irrigation, other agricultural inputs, and some measure of the new technology introduction, such as the percent of the crop produced from the new varieties. It is, however, a practical impossibility to obtain estimates of the parameters of such a relationship in the face of significant weather induced production variation and with a time series of only five or six years.

The approach taken here is to forego any attempt at country-by-country analysis and to concentrate on identifying a regional relationship between the adoption of new varieties and production, utilizing cross-section-time series data from several countries. This enterprise is also subject to data limitations, in that it is not possible to obtain aggregate data for all crop specific inputs for the Asian and Middle Eastern countries of concern. It is possible, however, to construct data on land and fertilizer use. Under reasonably plausible conditions, this limited data is sufficient to enable an estimate of the increased production associated with the high yielding varieties.

The basic model underlying the econometric specification in this and later sections of the paper is a simple productivity formulation. Suppose that the aggregate production function can be written

$$Y = f(f_b[X_b Q_b], f_m[X_m Q_m]). \tag{1}$$

The production function f is homogeneous of degree one and is written as a function of two "sub-processes," a biological process, f_b, and a mechanical process, f_m. Each process is a function of a vector of inputs (X_b, X_m) scaled into standard quality units by a vector (Q_b, Q_m). Sadan [1970], among others, provides some evidence that the elasticity of substitution between the two sets of inputs, X_b and X_m, is relatively low even though it may be quite high for different inputs within each process. For example, labor and mechanical equipment are quite substitutable in the f_m process. Our major interest here is in identifying the relationship between output, Y, and Q_b, the quality composition of the biological inputs. Utilization of plants with improved biological properties (from an economic point of view) represents a change in this quality vector.

If we make the assumption that the ratio of mechanical inputs, X_m, to land has remained unchanged since 1950 (or has changed smoothly over time in later specifications), the following estimable specification of (1) is possible:

$$Y_t/\overline{Y}_{50} = C(L_t/\overline{L}_{50})^{a_1} (F_t/\overline{F}_{50})^{a_2} \, \mathrm{EXP}^{a_3 HYV + a_4 (HYV)^2}. \tag{2}$$

In (2) cross section-time series data for the post-1950 period on the aggregate production of wheat (rice) relative to the average production in each country in 1948–50 are regressed on land, L, and fertilizer utilization, F_t (which is not commodity specific but is measured as fertilizer per acre in all major crops)[3] in a standard Cobb-Douglas fashion. If mechanical inputs, for which data cannot be obtained, are utilized in relatively fixed proportions to land, after 1950 in each country (proportions may vary by country) the estimated coefficient on the land variable will be the production elasticity not of land but of the land-mechanical process inputs bundle.[4]

Fertilizer and land are the major real inputs in the biological process of production. Plant seeds represent biological inputs in the normal sense, but seeds also embody biological characteristics of economic importance and value. If we accept the rather simplistic view that the green revolution varieties reflect the dominant change in biological input quality, Q_b, over the recent period, the inclusion of the HYV (percent of the crop acreage planted to green revolution varieties) and HYV^2 terms should identify their contribution.

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[2] See Evenson, Ruttan, and Houck [4] for a discussion of this early green revolution in sugarcane production.

[3] Note that production, land, and fertilizer are measured relative to the average levels in the 1948–49–50 period. We are thus analyzing only changes relative to that period.

[4] If "left-out" variable is perfectly correlated with an included variable, the estimated coefficient for the included variable will be biased. The bias will be the multiple of the true coefficient on the left-out variable times the correlation coefficient for the two variables.

The results of two regressions estimated from data for 13 wheat producing countries and 12 rice production countries from the Asia-Middle East and North African regions are reported in Table 1. They bear out the general expectations regarding the relationship between percent of high yielding varieties and production. The negative coefficient on the HYV squared terms reflects the diminution of the superiority of the high yielding varieties as the percentage of area planted increases. The wheat regression results indicate that the production effect of the earliest adoption levels of the high yielding wheats was very high, but that the net production effect diminishes rapidly. In fact, for the region the net contribution reaches zero at less than one third adoption. The apparent production effect of high yielding rice varieties at early adoption levels is considerably lower than for wheat. The rate of diminution is also lower, however.

These results are consistent with the fact that the wheats were adopted much more rapidly than the rices in the early stages of the green revolution. They are, of course, also consistent with the adoption patterns in many countries which suggest that adoption levels will fall far short of 100 percent. In many cases it appears that less than 50 percent of the wheat and rice area is likely to be planted to the high yielding varieties. The major factor underlying these results is simply that the relative superiority of any form of agricultural technology is related to soil, climate and economic conditions. Adoption occurs first in areas where relative superiority is greatest and spreads later to areas where the degree of superiority is lower.

Table 1. Regression analysis: high yielding varieties' contributions: simple model (2)[a]

Independent Variables	Wheat Production (13 Asian-Middle Eastern Countries 1948–71) 307 observations	Rice Production (12 Asian-Middle Eastern Countries 1948–71) 282 observations
LN (Land)	.9836 (.0030)	1.0374 (.0030)
LN (fert)	.0411 (.0058)	.0477 (.0021)
HYV	.0430 (.0018)	.0052 (.0010)
$(HYV)^2$	—.00085 (.00004)	—.00005 (.00002)
Constant	.1758	—.2208
R^2	.9859	.9965

[a] Dependent variable is LN (Production). Regressions are weighted by area harvested. Standard errors are in parentheses. Production, land, and fertilizer are scaled relative to average levels in 1948–49–50. HYV is the percent of the acreage of wheat or rice planted to "high yielding" varieties as defined by Dalrymple [2].

Availability of a controlled and adequate water supply has received major attention as a factor determining relative superiority of both the wheats and rices. Undeniably it is of major importance in this regard, but it is not the only factor. High yielding varieties (especially the earliest varieties) are sensitive to soil types, to temperature, to solar radiation, and other factors as well. A recent study of productivity gains in Indian agriculture, for example, did not reveal a high correlation of productivity gains with the existence of irrigation infrastructure (Evenson [3]).

These results, while a great improvement over the prior local comparative studies for purposes of analyzing the aggregate contribution of high yielding varieties, are still subject to serious limitations. Econometric limitations imposed by crude and meager data are fairly obvious. Coefficients on the land and fertilizer variables are reasonable and consistent with expectations, however.[5] The results may be biased by weather effects as well. The 1971 crop year in most of the region was probably abnormally poor. Unfortunately, we do not have data at hand to improve this basic formulation.

This simple model has treated new technology as being exclusively embodied in the high yielding rice and wheat varieties. For the entire period 1950–1971 this is surely unrealistic. The national research systems, even if relatively weak from a scientific standpoint, were contributing to productivity growth by producing at least some technology competitive with the Mexican and IRRI varieties. Furthermore, today most high yielding varieties being adopted are in fact the products of national research systems.

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[5] The coefficient on the land variable should be close to one if it is picking up the effects of the left-out variables (machinery-labor and animal power).

Toward a Richer Specification

The dominant role of the green revolution in recent agricultural development literature provides a very misleading picture of growth in agricultural productivity and of its determinants. This stems largely from a more general lack of understanding of the factors determining real economic growth. Many development projects have been designed on the premise that the LDC farmer was ignorant and unresponsive to economic incentives, that relevant technology was actually in existence, and that the "missionary" extension agent was the key to changing farmer values and attitudes and leading him to adopt modern methods. The consistent failure of these programs to produce the results expected of them created a setting in which the unexpected gains of the improved wheat and rice varieties were treated as a godsend. In a way they were, of course, and hundreds of poorly conceived development projects were at least partially "bailed out" as the agencies responsible for them moved quickly to associate themselves with the miracle wheats and rices.

The publicity generated in the process masked a number of important facts. These include the fact that considerable and important agricultural productivity gains had been achieved in many less developed countries in the 1950's and 1960's. Overall rate of productivity change in Indian agriculture was roughly the same from 1954 to 1960 as from 1966–1971 (Evenson [3]) (and India was the major green revolution country). Furthermore, we now have evidence that very little of this productivity resulted from the simple direct transfer of technology from developed countries.[6]

These factors limit the meaningfulness of the simple model discussed above. An extension which specifically incorporates two types of research activity in the less developed countries is set forth and subjected to test in this section. The extended specification is

$$(3)\qquad Y_t/\overline{Y}_{50} = C(L_t/\overline{L}_{50})^{a_1}(F_t/F_{50})^{a_2}$$

$$A_t^{(a_3+a_4S_t)}\ RA_t^{(a_5+a_6ZS_t+a_7[A_t+S_t])}$$

$$RY^{(a_8+a_9A_t)}$$

$$EXP^{(a_{10}HYV_t+a_{11}HYV_tA_t+a_{13}[HYV_t]^2+a_{14}t)}$$

The variables Y_t, L_t, F_t, HYV_t, and HYV_t^2 are as in (2). The variables A_t, S_t, RA_t, and ZS_t are measures of research activity. Each is measured as a cumulation of research activity from 1942 to time t as:

$$A_t = \sum_{1942}^{t-5} P_t + .8P_{t-4} + .6P_{t-3}$$

$$+ .4P_{t-2} + .2P_{t-1}.$$

The research measures are based on the number of publications (P_t) which have been screened for commodity relevance and for scientific significance by two international abstracting journals, *Plant Breeding Abstracts* and *Biological Abstracts*.[7]

A_t is a measure of the research undertaken in agronomy and plant breeding specifically with wheat or rice. S_t is a measure of research activity in plant physiology, phytopathology, and soil-science. This work is not commodity specific and represents agriculturally related scientific research activity. RA_t measures agronomic and plant breeding research activity in countries other than the country in question, but which are in the same *geo-climate region*. ZS_t measures agriculturally related scientific research in other countries located in the same *geo-climate zone*. RY_t is a measure of the average level of cereal grain yields in other countries in the same *geo-climate region*. All research variables are expressed on a per sub-region basis.

The latter three variables are designed to incorporate geographic technology transfer specifically, if somewhat crudely, into the analysis. The geo-climate regions and zones are defined as modifications of the agricultural climate classification of Papadakis [7] and are discussed extensively in Evenson [3]. Table 2 provides summary information for 33 major geo-climate regions grouped in nine geo-climate zones. For purposes of this paper, geo-climate zone 1 includes most of the LDC rice production, and geo-climate zones 1, 3, and 4 include the LDC wheat producing areas.

Table 2 indicates the 1971 levels of the variables. A_t and S_t are expressed on a sub-region basis. The A_t variable is reported for each significant crop produced in the region and for all cereals. These measures give an indication of

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[6] See Kislev and Evenson [6] for an analysis of technology transfer in wheat and maize production.

[7] The screening of the abstracting journals is very important. Not only does the screening and classification allow an internationally consistent measure of commodity specific agronomic research, but it imposes a quality standard. Roughly one third of the publications from U. S. Agricultural Experiment Stations are included in this measure, for example, Kislev and Evenson [6].

Table 2. Geo-climate region research in cereal grain production[a]

	Publications (1942–70) per Sub-Region									Cereal Grain Yields		
Region #	Wheat	Barley	Maize	Sorghum	Rice	Cer. Pub. per Sub-Region	Basic/Crop Pub./Pub.	Adjusted Number of Sub-Regions	LDC Share	1950–51 (Kg/ha)	1966–67 (Kg/ha)	Ratio
						A_{71}	S_{71}/A_{71}					
1. Tropical Zone						48.3	.90			11.00	13.79	1.25
1.1 Humid Equatorial	—	—	30.2	11.6	111.8	51.6	1.06	15.91	1.00	11.92	14.33	1.20
1.2 Humid Tropical	1.5	.2	15.1	2.1	121.7	28.1	.32	5.00	.86	16.98	24.62	1.45
1.3 Dry Equatorial	—	—	4.7	1.1	22.5	8.2	1.53	4.06	1.00	10.61	14.53	1.37
1.4 Hot Equatorial	8.4	—	19.3	13.6	224.5	68.7	.96	10.22	.95	10.57	13.58	1.28
1.5 Semi-Arid Equatorial	.0	—	4.1	32.2	8.6	8.6	.65	6.35	1.00	8.46	10.69	1.26
1.7 Humid Tierra	20.4	20.4	30.6	26.0	20.8	24.1	.85	16.19	1.00	12.38	12.91	1.04
1.8 Dry Tierra	—	—	42.4	—	18.1	52.8	.50	2.06	1.00	14.49	10.11	.70
1.9 Cool Winter Tropical	—	—	18.5	87.4	353.1	144.9	1.00	5.58	.86	10.39	13.77	1.33
2. Tierra Fria Zone						52.1	.62			7.93	12.84	1.62
2.1 Tropical Highlands	8.0	6.7	132.9	28.2	—	52.1	.62	8.72	1.00	7.93	12.84	1.62
3. Desert Zone						15.6	2.69			9.22	12.05	1.31
3.1 Hot Tropical	.0	—	2.0	—	4.5	2.3	.22	3.00	1.00	28.28	31.86	1.13
3.2 Hot Subtropical	20.9	11.8	—	—	6.7	15.8	.76	16.94	1.00	8.99	11.80	1.31
3.7 Continental	1.4	1.6	.0	.0	93.5	24.5	6.26	4.00	.60	9.98	11.83	1.19
4. Subtropical Zone						54.9	1.18			6.83	9.01	1.32
4.1 Humid	30.4	4.7	51.6	1.6	63.0	28.4	1.20	9.22	.75	12.50	15.65	1.25
4.2 Monsoon	116.6	128.1	69.7	144.9	52.0	102.7	1.31	6.91	.66	6.41	8.16	1.27
4.3 Hot	105.7	46.7	47.6	156.8	6.6	68.7	.99	6.05	1.00	5.21	7.41	1.42
4.4 Semi-Arid	—	—	10.0	5.0	—	7.5	.80	2.00	1.00	14.21	17.93	1.26
5. Pampean Zone						97.3	1.23			13.61	16.73	1.23
5.1 Pampean	99.5	99.0	168.4	36.6	—	97.3	1.23	4.53	.20	13 61	16.73	1.23
6. Mediterranean Zone						39.6	1.95			10.14	13.03	1.28
6.1 Subtropical	72.9	71.3	33.5	11.7	104.9	55.4	2.59	18.68	.45	10.38	13.10	1.26
6.2 Marine	14.0	2.2	34.4	12.0	.0	16.8	.80	7.24	.25	9.20	13.32	1.45
6.5 Temperate	77.3	18.9	45.5	4.0	23.5	37.4	1.90	11.27	.17	11.93	15.86	1.33
6.7 Continental	67.0	27.7	133.4	8.3	1.6	47.5	1.41	19.68	.30	10.79	14.48	1.34
6.8 Subtrop. Semi-Arid	46.9	22.8	21.3	6.0	—	26.7	1.68	14.26	.50	8.64	9.75	1.13
6.9 Contin. Semi-Arid	4.6	3.0	9.0	1.0	—	5.8	.20	4.61	.66	6.16	6.48	1.05
7. Marine Zone						120.1	2.02			17.01	28.13	1.65
7.1 Warm	11.5	5.4	—	—	—	8.4	2.00	2.00	.00	25.13	35.48	1.41
7.2 Cool	78.9	236.3	92.9	—	—	136.1	3.10	6.81	.00	22.12	34.82	1.57
7.6 Cool Temperate	97.1	145.8	158.9	20.3	—	120.3	1.75	21.71	.03	18.44	28.86	1.57
7.7 Cold Temperate	90.6	144.8	187.9	—	—	133.9	1.46	8.00	.00	9.62	20.79	2.16
8. Humid Continental Zone						256.2	2.79			19.61	34.02	1.74
8.1 Warm	152.4	151.2	450.5	92.2	417.0	254.3	4.60	7.62	.00	24.43	42.54	1.74
8.2 Semi-Warm	164.3	124.1	703.0	283.5	622.3	291.5	1.50	12.16	.00	18.77	33.55	1.79
8.3 Cold	52.0	17.0	—	—	—	34.5	.63	2.00	.00	7.98	11.90	1.49
9. Steppe Zone						357.9	1.35			11.57	18.26	1.58
9.2 Semi-Warm	606.5	346.6	818.6	304.2	24.7	450.3	1.10	12.92	.00	12.29	21.14	1.68
9.3 Cold	636.4	348.5	111.9	12.0	—	382.3	1.75	7.28	.00	10.11	14.82	1.47
9.4 Temperate	38.2	35.5	—	—	—	36.9	1.96	4.34	.00	11.35	17.36	1.47

[a] Publications data from [5]. Sub-regions are defined as $n(1-d)+d$ where n is the number of individual countries in the region, and $d=\sum_{i=1}^{n} A_i-\bar{A}/(2A_i-2)\bar{A}$. A_i is the acreage of the crop in country i. The term $d=0$, when all countries in the region have the same acreage, approaches 1 as acreage in the region is concentrated in one country. Cereal grain yields are computed by simply totaling cereal production of the different grains without price weighting. While prices vary considerably by country, international prices per Kg are approximately the same for all cereals.

research activity per major research problem. As Table 2 indicates, the relative levels of research activity in the largely developed climate zones (7, 8, and 9) have been roughly five times as great as the levels in the less developed climate zones (1, 2, 3, and 4). Disparity in research activity in the supporting sciences (S_t) is much greater. The cereal yield data shown in the table give a crude indication of economic performance by region.

Table 3 reports regression results based on the more complex specification. The wheat and rice regressions indicate that indigenous research activity has influenced productivity gains. The high yielding variety variables included in the regressions indicate that the green revolution also contributed independently to productivity growth. In both the wheat and rice regressions the negative interaction term between high yielding varieties and agronomic research indicates that the margin of superiority of the high yielding varieties is lower, the higher the level of national agronomic research activity. Inclusion of the national research system variables lowers

Table 3. Regression analysis based on specification (3)[a]

	Wheat Production	Rice Production	Cereal Grains Production
Independent Variables	13 Asian-Middle Eastern Countries 1948–71 307 Observations	12 Asian-Middle Eastern Countries 1948–71 282 Observations	20 Asian-Middle Eastern Countries 1948–71 1050 Observations
LN (Land)	.9887	.9756	.9867
	(.0010)	(.0016)	(.0015)
LN (Fert)	.0120	.0419	.0796
	(.009)	(.0054)	(.0052)
HYV	-.0049	.0234	.0212
	(.0035)	(.0019)	(.0014)
HYV^2	.00016	—.00051	—.00038
	(.00002)	(.000005)	(.00010)
$HYV*A$	—.00001	—.00001	.000001
	(.000002)	(.00001)	(.000001)
$LN(A)$	—.0061	.0356	—.0033
	(.0020)	(.0040)	(.0021)
$LN(A)*S$	—.00029	.00002	.00011
	(.00002)	(.00001)	(.00001)
$LN(RA)$	—.0111	—.0359	.00077
	(.0025)	(.0024)	(.00800)
$LN(RA)*ZS$	.00037	.00089	.00067
	(.00003)	(.00001)	(.00006)
$LN(RA)*(A+S)$	—.00037	.00066	.00012
	(.00005)	(.00013)	(.00001)
$LN(RA)*(A+S)^2$			—.0000010
			(.0000001)
$LN(RY)$			—.066
			(.025)
$LN(RY)*A$			—.00059
			(.00006)
Time	.012	—.018	*
	(.001)	(.003)	
Constant	—.377	1.22	.98
R^2	.9983	.9905	.9924

[a] Regressions are weighted by acreage. Standard errors are in parentheses.

* Crop specific time trends are included in the equations.

the estimated production effect of the high yielding wheats.

The regressions do reflect a significant degree of international transfer of research findings in both wheat and rice production. In fact, the dominant research variable in regressions for both wheat and rice is the interaction variable of regional agronomic research and zonal supporting science research ($LN[RA]*ZS$). The wheat regression shows complementarity between indigenous and regional research while the rice regression shows substitutability. That is, the higher the level of indigenous research on wheat, the more valuable is regional research on wheat. For rice the higher the level of indigenous research, the less valuable the regional research.

The regression based on cereal grains production in the Asian-Middle Eastern region probably identifies the underlying relationships between research activities and productivity growth best. It indicates that for all cereal grains:

1. National agronomic and plant breeding research has contributed significantly to realized productivity growth. In addition to a direct contribution to the economy in which the research is conducted, an indirect contribution to other economies in similar geo-climate regions has been realized.

2. Indigenous research programs are complementary to regional research contributions at low levels and substitute for regional or transferred research at high levels.

3. In the case of both indigenous and trans-

Table 4. Computed dollar value of the production due to high yielding varieties[a]

(Millions of 1970 U.S. Dollars)	1970–71	1969–70	1968–69	1967–68	1966–67	1965–66
Wheat	2,173	1,488	1,443	957	174	.03
Rice	1,206	912	555	310	120	.001

[a] Based on Table 3.

ferred research contributions by agronomic and plant breeding research, the *indirect* contribution of supporting scientific research in plant physiology, phytopathology, and soil science has been very significant. In fact, the apparent marginal contribution to production of a dollar expended on supporting scientific research exceeds that of the applied agronomic and plant breeding research.

4. It would appear that most technology transfer takes an indirect rather than a direct form. The regional yield variables do not dominate the regional research variables. The negative interaction term between regional yield levels and indigenous agronomic research indicates that indigenous research is indeed producing substitute or competing technology. Much of the transfer apparently takes the form of "knowledge" as opposed to tangible technology. Regressions (not reported here) which included research conducted outside similar geo-climate regions indicated no contribution forthcoming from this research.

Given the crudity of these data and the possible errors of measurement, a strict hypothesis testing interpretation of the reported standard errors is probably not justified. Nonetheless, the overall statistical quality of the results seems high enough to warrant a discussion of policy implications.[8]

Policy Implications

This analysis reaches the conclusion that while the high yielding varieties did contribute very significantly to increased production, they were by no means the sole source of productivity gains in LDC agriculture. A crude "growth accounting" (based on the cereal grains regression in Table 3) indicates that less than 25 percent of the productivity gains (net of land and fertilizer contributions) realized in cereal grains production are associated with the high yielding varieties. (For the period since 1966, of course, the proportion is much higher than this.) The remaining growth is about equally accounted for by indigenous research discovery and regional or borrowed research discoveries.

The contribution of the high yielding varieties computed from this study is given in Table 4. Obviously these contributions have been of major importance. Interestingly, this contribution continues to increase into 1970–71.

Even if the rate of adoption of high yielding varieties slows significantly in the near future, there is basis for some optimism in this analysis. The national research systems in the region have been undergoing relatively rapid development in the 1960's and should be contributing significantly to productivity growth in the 1970's and 1980's. An aggressive policy of investment in these systems can more than offset the slowdown in the green revolution contribution.

The finding that the discoveries of researchers are transferred within the particular geo-climate regions defined here but not across those regions to any appreciable extent has obvious implications. The task of building first rate research institutions in countries and regions with limited supplies of scientific skills is indeed difficult. It appears that there are no alternatives. Surely more aggressive action toward this objective is called for.

Finally, these results indicate that the most productive research at the margin is not the applied agronomic and plant breeding research, but the supportive science research. Computations based on Table 3 indicate that a dollar expended on agronomic research will produce an expected stream of increased product which rises over a period of 12 or so years to a level of $2.50 in the country undertaking the research. In addition the research benefits other countries by a similar amount. A dollar invested in supportive science research has an expected benefits stream of approximately $3.00 which the conducting country might appropriate, but a much larger contribution (on the order of $8 to $10) to be transferred to other producing countries.

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[8] In further works, several modifications are planned, including the use of Nerlove-Balestra estimating techniques.

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Discussion: JERE R. BEHRMAN, *University of Pennsylvania*

The title of this paper vastly overstates its scope. Evenson makes no attempt to evaluate the myriad developmental effects of the Green Revolution in dimensions such as income distribution and international trade. Instead he concentrates exclusively on the question of the relative contribution of international versus national or regional research efforts in increasing the production of basic food grains in Asia and North Africa. Such a question is an important one because of the tendency to overemphasize the contribution of the former. It is also a difficult one to explore. Evenson's attempt to explore it is bold and imaginative. I commend this effort. The four sets of questions raised below should not be interpreted to detract from my basic enthusiasm for this effort.

(1) Key to the study is the specification of the research output measure. In many respects Evenson's choice of the index from the abstracts is ingenious. It focuses on output rather than input. It eliminates the need to be concerned with appropriate exchange rates for cross-country comparisons that many input measures would require. It permits a crop-specific index of research output. It avoids a large number of problems such as identifying whether or not specific expenditures were in fact for research.

But I am left with some reservations. Might it be biased towards the output of particular institutions (e.g., government research stations or universities)? How does it compare with other possible measures (e.g., input measures)? Is it subject to fads in research? Is the nation-state an appropriate unit given the considerable differences in size among the included countries? Evenson probably can allay much of my doubt. It would be useful if he were to do so in this study by commenting more on his indices.

(2) Other inputs are treated in a rather cavalier fashion. Admittedly the data problems are horrendous. But some evidence (such as the other paper presented at this session) casts doubt on the legitimacy of the dichotomization between mechanical and biological sub-processes. The assumption that the ratio of mechanical inputs to land has remained constant (or smoothly changed) since 1950 is very strong. Other observers of change in developing agriculture have placed considerable emphasis on other factors such as the quality and quantity of water control systems, the quality of human inputs, and the nature of the infrastructure. It would not be surprising if changes in some of these other inputs were fairly highly correlated with the changes in the research variables. If so, the coefficients of the latter may be biased upwards.

(3) No attempt is made to recognize the structure of the disturbance terms due to the combination of time series and cross section data. I applaud the author's intent (stated in note eight) to investigate the impact of this structure more carefully.

(4) Several aspects of the conclusions are bothersome.

First, Evenson seems to suggest that although the returns to international research on high-yielding varieties were high, lags in previous research had created a one-shot potential. Future research therefore probably is better conducted at regional and national levels. That conclusion may be true for the grains under consideration. But might there not be other products for which past neglect has created the potential for quite substantial returns from international research efforts?

Second, Evenson notes that by a crude growth accounting, only about 25 percent of the productivity gains realized in cereal grains were associated with high-yielding varieties. But this accounting apparently is for the entire 1950–1970 period even though the impact of the high-yielding varieties was limited to the post-1965 years. Given that they accounted for a quarter of the productivity growth over two decades even though they were available only for the last quinquennium, the high-yielding varieties must have been very important for the post-1965 years in which they were available. It seems quite strange to include earlier years in Evenson's growth accounting since the contribution of the high-yielding varieties could be made about as small as desired simply by extending the time period back further.

Third, Evenson suggests that his results support the direction of more resources to local, as opposed to international, research efforts. Unfortunately, no such inference is legitimate because there is very limited consideration of the costs of the alternative research efforts. Moreover there is no basis for evaluating the desirability of devoting resources to research versus other factors (see point two above) since neither the contribution nor the cost of the latter is incorporated into the analysis.

Discussion: E. J. R. BOOTH, *University of Connecticut*

At the risk of sounding trite, I really did enjoy the challenge of a thorough reading of Dr. Binswanger's paper. It is certainly worth at least that and will reward the reader with more than the specific conclusions the paper reached. I thank the author for his consideration in providing me with a clear copy of his paper in such good time as to leave me no excuse from a careful critique.

Let me begin the discussion with three small bones of contention that may be due to misunderstanding—either mine or his.

(1) It is rarely necessary to impose homogeneity of degree one on the production process to arrive at estimation equations. The fact that cost functions are homogeneous in prices is irrelevant to the estimation of cost functions that include output as an explanatory variable. What this homogeneity imposes is restrictions on certain mathematical forms of the (minimum) cost function. The fact that cost functions are homogeneous follows from the definition of cost to which the function must always conform. Doubling factor prices may indeed affect factor ratios when output is allowed to vary and the production function is not homothetic; otherwise doubling prices will not even affect factor amounts.

(2) Having factor prices as independent variables is an improvement over having factor amounts as right-side variables, but not, I venture, for the reason given. I have never been much impressed by the argument, which dates back at least to L. R. Klein [1], that inputs are endogenous variables for firm decision-makers and thus should not be used as independent variables in estimating parameters of aggregate production functions. First, Klein included output as one of the variables subject to simultaneous entrepreneurial decision, and output is on the right side of a cost function. Second, in the output-input decisions for one industry the causal flow from input to output seems fairly secure once these amounts have been decided upon for whatever reasons. Least-squares bias in production functions is perhaps more a phenomenon of aggregation than of specification and more often to be found in time series studies than in cross-sectional ones.

Factor prices, on the other hand, are often more easily obtained as data than factor amounts. As an example of this, Binswanger's Appendix discussion of the land variable is most appropriate. Even when there are no problems concerning differential quality or rate of use of a stock of input, it is still easier, as with labor for example, to find a wage rate reported than to find the actual hours worked.

(3) Constraints are always imposed on elasticities of substitution and therefore of factor demand. For example, the cost-share weighted sum of partial substitution elasticities must always vanish for any form of the production function. This amounts to the well-known restriction on the number of complementary relations between inputs in production (or between goods in consumption). In general, there can be no more than $(n-1)(n-2)/2$ distinct pairs of complements among n inputs which means six for the paper's five input classes. In the functional form (19) this is equivalent to the second restriction in (20) providing output is viewed as fixed.

In my opinion the main benefit of the cost function approach is that substitution elasticities can be estimated directly together with estimates of their sampling errors. This feature is well exploited in the paper although I do wish rather more space had been used to discuss the policy implications of the signs and sizes of these estimates. The data and the estimation procedures are all well conceived and executed considering the problems encountered, but I do have one major question about the model that cuts across the whole study. And I emphasize it is a question, not a criticism and certainly not very constructive.

The conclusions concerning the relationship between elasticities of substitution and factor cost shares summarized in equation (15) all depend on the assumption that the entrepreneurs generating the data were cost minimizers at fixed output levels. If we assume that they were also profit maximizers, certain modifications ensue.

The conclusions regarding cost are not changed since cost minimization is an implication of profit maximization. However, output becomes an "improper" right-side variable which could cause least-squares bias and multicollinearity. Input prices certainly affect the level of profit-maximizing output to be observed. Also, output would be determined by entrepreneurs in relationship to its market price. In this case, the differential of the first-order system (8) and (9) should include a recognition that output depends on its price. If this is done, then (15) must be modified to include the effects of output demand elasticity on the elasticities of input demands.

But is output to appear in Binswanger's estimation equations? It seems to in (19) and (21), but where did it go in (28)? It became a proxy for technical change measured as time. So output really is to be held fixed (and cost minimized), and any difference in output level observed over the sample years is to be assumed due to differences in efficiency and not to profit-maximizing response to changes in factor prices. So why not use output in the estimating equation? Apart from the difficulty of aggregating output across goods and regions, technical change would still have to be accounted for to correct the problem of bias that the author recognizes.

It seems to me that the question is quickly resolved if (21) is treated as not necessarily belonging to the Translog function and thus not needing to include output at all. There must be many forms of cost functions that are additive in output (or in its logarithm). None of the results concerning the relations between the elasticities and the factor price parameters (22) through (25) depend on the inclusion of output in (21). The only unresolved problem, as I see it, is whether the output-price elasticity of demand should be included in derivation of (15). And this depends on the model assumed. The fact that output elasticity is pretty small anyway is comforting. The fact that the estimates seem reasonable compared to *a priori* expectation and to other recent results provides more comfort.

The one case of significant complementarity (labor and fertilizer), the traditional substitutability of land and fertilizer, and the subtle substitution of machinery for land and labor should all provide useful guides for policy especially if the techniques so expertly applied in this study were tried out successfully in less developed agricultures.

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ENERGY SUPPLY AND DEMAND IN THE UNITED STATES

CHAIRMAN: DUANE CHAPMAN, CORNELL UNIVERSITY

Incentive Policy and Supplies of Energy Sources

STEPHEN L. MCDONALD

THE OCCASION for this session is the so-called energy crisis in the United States, and it is well to begin with a statement of my perception of it. As I see it, the crisis represents a present and prospective excess demand for energy, particularly for energy derived from oil and gas, which apparently cannot be eliminated without sacrifice of one or more present objectives of public policy, specifically security of fuel supply, environmental protection, and stable living costs. The crisis arises out of an increasing supply price of oil and gas from domestic sources accompanied by general and specific price regulation, oil import restrictions, and growing efforts to prevent environmental damages (e.g., from the burning of high-sulphur coal), and is complicated in the short run by very low supply and demand elasticities. If one takes seriously the objectives of security of supply and environmental protection and distinguishes between regulation of individual commodity prices and control of the general price level, as I do, then it is clear that the solution of the problem called the energy crisis involves either higher absolute and relative prices for oil and gas or the creation of artificial non-price incentives to increase the supply of or decrease the demand for these energy sources.

The topic assigned to me is incentive policy on the supply side. I shall concentrate on oil and gas, discussing both price and non-price incentives. Of primary concern will be present incentive policy as it would be modified by the proposals of President Nixon in his message to the Congress of April 18, 1973 [13]. I shall try to appraise both qualitatively and quantitatively the supply effects of the President's proposals and the remaining special tax incentives affecting oil and gas production.

In the message referred to, President Nixon announced three pertinent actions taken on his own authority. These were the abolition of the old quota system of limiting oil imports and the substitution of a fee-for-imports system, delay in the imposition of certain environmental protection standards that would limit the burning of high-sulphur coal, and acceleration of the rate of leasing of prospective oil and gas lands in the Federal domain on the outer continental shelf. He additionally proposed to the Congress legislation to free "new" gas in interstate commerce from price regulation, to facilitate construction of the Alaskan pipeline, to extend the investment tax credit to expenditures on exploratory drilling for oil and gas, to facilitate the siting of deepwater ports and nuclear power plants, to encourage various measures of energy demand reduction, to initiate an oil shale leasing program on a pilot basis, and to double the rate of Federal financing of research and development in the energy field. Most of these actions or proposals affect demand, call for governmental in lieu of private action, or merely facilitate private action induced by existing incentives. Those that do (or would) have new incentive effects are the change in the import control system, the freeing of "new" gas from price control, and the extension of the investment tax credit to exploratory drilling. It is the latter that I shall discuss, together with the remaining tax incentives affecting oil and gas production.

Modification of the Oil Import Control System

From March 1959 to April 1973 crude oil and products imports into the United States were limited by the Mandatory Oil Import Quota Program, the principal restraint under which was the restriction of crude oil imports into the area east of the Rocky Mountains to 12.2 percent of production within the area [3, pp. 115–130]. There was also a tariff on crude and fuel oils rated at 25 degrees API or more of 10.5 cents per barrel, on gasoline and other motor fuels of 52.5 cents per barrel, and on other products of 10–84 cents per barrel. By proclamation effective April 18, 1973, the President abolished the quota system and the indicated tariffs and instituted a system of essentially free imports up to the level of previously established 1973 quota allocations. For imports

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in excess of 1973 quota allocations, fees must be paid, the level of the fees increasing gradually on a regular time schedule through 1975. From 1973 through 1975 the fees will rise from 10.5 cents to 21 cents per barrel of crude oil, from 52 cents to 63 cents per barrel of gasoline, and from 15 cents to 63 cents per barrel of other finished products. The portion of the 1973 quota allocation that is free of import fees will gradually decrease on a regular time schedule from 100 percent in 1973 to zero percent in 1980 [1]. Thus on crude oil, for example, the effective tariff in 1973 falls from 10.5 cents per barrel of *total* imports to 10.5 cents per barrel of imports in *excess of the 1973 quota allocation;* but by 1980 it will rise to 21 cents per barrel of *total* imports. Because of the new fee system, the supply price of imported oil immediately falls but then gradually will rise through 1980 to a level above that of 1973 prior to the Presidential proclamation.

The apparent reason for the President's abolishing the quota system was that by early 1973 domestic production of oil plus the quota promised to fall short of demand at an acceptable price. His apparent motive for immediately reducing the effective tariff and then raising it gradually to a new higher level was to encourage additional imports in the short run as a means of eliminating excess demand, but then to provide a growing incentive to domestic production so that by 1980 an acceptable proportion of demand would be supplied from domestic sources. We are not informed as to his target division of supply between domestic production and imports, but we can ask the question: will the projected higher import fee make a significant difference in the share of domestic production by 1980?

Confining ourselves to the case of crude oil and assuming that the supply of imports is perfectly elastic at a price determined by the OPEC group, the answer to this question depends, of course, on the percentage increase in supply price caused by the higher effective tariff, the long-run elasticity of demand for crude oil, and the long-run elasticity of crude oil supply from domestic sources. As this is written, the partially-controlled price of domestically produced crude oil is about $4.50 per barrel, and spot prices of imported oil range up to $7.00 per barrel. I estimate that if controls were removed, the equilibrium price would be about $5.00 per barrel. On this base the projected increase in tariff of 10.5 cents per barrel from 1973 pre-proclamation to 1980 is approximately 2 percent, which, given the import supply assumption, would be the percentage increase in equilibrium price caused by the increased tariff. For the elasticity of demand I shall use the figure originating with the Exxon Corporation and accepted by the Cabinet Task Force on Oil Import Control in its report, that is, —0.1 [3, p. 38].

For an estimate of the long-run elasticity of crude oil supply from domestic sources I shall rely on two studies employing quite different methods. The first of these is by Erickson and Spann [5], who follow Fisher [7] in methodology. Using data from the period 1946 to 1959, they estimate a supply elasticity of 0.93. This figure is the algebraic sum of three elasticities with respect to price in their model: the elasticity of wildcat drilling (+1.48), the elasticity of the success ratio (—0.13), and the elasticity of average size of discovery (—0.42). The model and results imply that in response to an increase in price, oil operators sharply increase the rate of wildcat drilling, partly on prospects that are poorer than average. In effect, they reach down deeper in their existing inventory of prospects, taking on poorer risks than would have been justified at lower prices. Since there is no long-term downward trend in the success ratio, the effect observed must be a transitory one. Thus the estimated supply elasticity is one of intermediate term—a period of time long enough to change the rate of drilling but not long enough to replenish the inventory of prospects through preliminary exploration—rather than one of long term. In the long run the above negative elasticities would be smaller or absent altogether, so that the net elasticity of supply would be larger.

This conclusion is strengthened by consideration of a second, quite different kind of study presently in draft form, made by Davidson, Falk, and Lee [4] for the Energy Policy Project, sponsored by the Ford Foundation and cited here by permission of the authors and the director of the Project, David Freeman. On the principle that economic rent is the difference between the value of output and long-run marginal cost, the authors estimate the elasticity of long-run supply from the share of the value of oil and gas produced going to rent—annualized lease bonuses plus royalties. Their formula for long-run supply elasticity, the derivation of which I shall not take space to reproduce here, is $1 - a/a$, where a is the share of rent. It is readily seen from the formula that elasticity goes from zero toward infinity as the rent share goes from one toward zero. Using data from the U. S. outer continental shelf for the years 1953 through 1971, the authors find the average share of rent in total output to be 0.42, implying an average elasticity of 1.37. They observe an upward trend in the elasticities computed year by year, 1953–71, and indicate that the trend value reaches 2.0 in the late seventies. They note that the true elasticity of supply may be even higher than calculated because the federal government, by limiting the rate of leasing on the shelf, may have captured some monopoly profits in the nominal form of rent. They conclude accordingly that the long-run elasticity of supply on the shelf is at least 1.0 and may well be as large as 2.0.

This conclusion must be qualified in at least two ways. First, it does not necessarily apply to areas other than the outer continental shelf. This is not a major fault, however, since it is believed that most of the oil remaining to be found in the United States, other than in Alaska, is on the shelf. Second, while the ingenious technique of Davidson, Falk, and Lee [4] is well designed to capture a truly long-run elasticity, the measure they get is a sort of hybrid because the output employed in the calculation includes both oil and gas. Indeed, the trend they observe in the annual shares of rent and implied elasticities may be due to a trend in the proportion of gas to oil in new discoveries. So we cannot be sure that the elasticity calculated is that of oil alone. Nonetheless, in the light of the Erickson-Spann findings [5] using a different method, I feel safe in assuming a long-run elasticity of supply of crude oil from domestic sources of at least 1.0.

Let us now return to the original question of the effect of the ultimately higher crude oil tariff on the division of supply between domestic output and imports. Suppose that as the recent past suggests, the U. S. demand curve for crude oil shifts to the right at a rate of 4 percent per year for a total increase of 31.6 percent from 1973 to 1980. With a demand elasticity of —0.1 and a rise in price due to the higher tariff of 2 percent, total consumption will increase 31.3 percent. Assuming a domestic supply elasticity of 1.0, domestic production will supply two percentage points of that, leaving 29.3 percentage points, or 93.6 percent of the total increase in consumption, to be supplied from additional imports. If we increase the assumed domestic supply elasticity to 2.0, the percentage of the increase in consumption to be supplied from additional imports falls to 87.2. This latter implies that imports of crude oil will rise from about 20 percent of total consumption at present to about 37 percent in 1980.

It must be concluded that the ultimately higher tariff on crude oil embodied in the President's proclamation modifying the import control program will have little effect in checking the growth of imports as a share of domestic consumption. The incentive provided to domestic production is simply too small to make much difference. The actions of the OPEC group in periodically raising the price of imported crude oil are likely to swamp the increased tariff in determining the rate of growth of the share of imports in total U. S. consumption.

Deregulation of "New" Gas Prices

Since 1954 the wellhead price of natural gas dedicated to interstate commerce has been regulated on a cost-of-service basis by the Federal Power Commission. Apparently this regulation has prevented the price of gas from rising as fast as replacement cost, for during the period of regulation the reserves-to-production ratio has fallen by half, from 25:1 to 12:1 [15, p. 64]. Imports through pipelines from Canada and Mexico are severely limited by their governments, and overseas imports in liquid form can be landed in the United States only at costs two or three times the delivered cost of domestic pipeline gas. The substitution of gas for coal and fuel oil in industrial boilers has been stimulated by environmental regulations, for gas is relatively free of adverse environmental effects in its production, transportation, and combustion. Under these circumstances American consumers of gas must either pay higher prices or submit to rationing.

Facing this fact, President Nixon announced in his message to Congress of April 18 this year that he was proposing legislation to free from price regulation gas from new wells, gas newly dedicated to interstate markets, and gas produced after expiration of existing contracts. The proposal represents a compromise between the opposing interests of gas producers, who want all gas prices freed of regulation, and gas consumers, who want low prices but adequate supplies. As the President notes, the proposal if enacted will provide an incentive to new exploration and will eventually lead to greater quantity supplied (movement along the long-run supply function), but it will only gradually increase the average cost of gas to consumers as old gas contracts expire and will prevent massive windfall profits, or rents, to owners of gas discovered at lower costs in the past.

The question for us is, how much of an incentive in the form of higher price will be required to equate supply with demand by, say, 1980? As with oil, the answer depends on the rate of shift in the demand curve, the elasticity of demand and the elasticity of supply. Since gas is a subordinate joint product with oil, it also depends on the assumed course of oil prices.

As for the elasticity of demand for gas, Balestra and Nerlove [2] estimate a figure of —0.7 on the basis of 1950–62 data. Tummala [16], using several different methods and employing 1946–64 data, gets a range of —0.7 to —1.33 in industrial uses and a range of —.44 to —1.63 in commercial and residential uses. It is likely that the absolute size of demand elasticity will increase as prices rise steeply in the years ahead, so it seems reasonably conservative to assume for our purposes a figure of —1.0.

We have three highly consistent estimates of the long-run elasticity of supply of natural gas. Using data for 1955–69, Garrett [8] gets a figure of 0.5. Erickson and Spann [6] estimate gas supply elasticity to be 0.69 on the basis of data spanning 1946–59, but their findings include *positive* elasticities of success ratio and discovery size, the opposite of their findings for oil, which they are inclined to discount as the transitory effect of an inventory of large gas prospects set aside when gas findings were relatively unprofitable and drawn upon increasingly as gas prices improved in relation to oil prices. Allowing for this apparently transitory effect, Erickson and Spann give an elasticity of 0.5 as their "best judgment." The finding of MacAvoy [10], 0.45 on the basis of 1954–60 data, using a different supply model, tends to support their judgment. We may add that the lower supply elasticity for gas than oil is consistent with the fact that gas is a subordinate joint product with oil: a rise in gas prices of a given percentage increases prospective revenues from exploration less than the same percentage increase in oil prices. Thus Erickson and Spann find the elasticity of wildcat drilling to be 1.48 with respect to oil prices and only 0.35 with respect to gas prices. So we shall use a figure of 0.5 as the long-run elasticity of gas supply with some confidence.

Returning to the question of the necessary rise in equilibrium price, suppose the demand curve for gas shifts to the right at 8 percent per year, a figure consistent with the recent trend in consumption, or a total of 71 percent to 1980. A supply curve of 0.5 elasticity and a demand curve of —1.0 elasticity would intersect at a distance of approximately one-third of this percentage increase to the right of the 1973 equilibrium. That is, consumption would increase about 24 percent from 1973 to 1980. This implies a necessary increase of 48 percent in the relative price of natural gas. If we assume inflation at 3.5 percent per year to 1980, the necessary rise in the absolute price of natural gas is approximately 88 percent, from an estimated new contract field price of 30 cents/mcf in 1973 to 56 cents/mcf in 1980. If we allow for the fact that there is excess demand in 1973, the price increase must be larger than indicated to achieve equilibrium in 1980.

In a recent article MacAvoy and Pindyck [11] develop an econometric model of the gas economy using numerous independent variables, including growth rates of value added, per capita income, capital additions, population, alternative fuel prices, drilling costs, and the general price level. They assume that inflation will persist at the rate of 3.5 percent per year to 1980, while the absolute prices of fuels alternative to gas will rise at the rate of 8.5 percent per year. Simulating the model for the period 1972–80 under the assumption of deregulation of gas prices, they get an equilibrium new contract field price of 65.5 cents/mcf in 1980, a result not inconsistent with the estimate of ours when allowance is made for initial disequilibrium in the gas market.

It is interesting to note that the price of crude oil affects the equilibrium price of natural gas from both the supply side (the joint product effect) and the demand side (the substitute fuel effect). A higher price of crude oil increases the supply of natural gas but also increases the demand for it. We do not know the relative weights of these effects, so we cannot say with certainty what effect OPEC price policy or our own oil tariff policy will have on the equilibrium price of natural gas.

In any case, it appears that the incentive responses in the natural gas economy are such that if we deregulate prices in interstate commerce, we can have an equilibrated market in 1980 with about a 50 percent rise in the relative price of gas. Such a price is far below that of liquefied gas shipped from Africa or the Middle East, variously estimated at $1.00–1.50/mcf, so deregulation, whatever its other merits and demerits, would be cheaper to the American consumer than its alternative. The President's proposal would provide incentives while minimizing both windfall gains to producers and royalty owners and windfall losses to consumers now committed for a time, through in-place durable combustion equipment, to gas as a fuel.

Extension of the Investment Tax Credit to Exploratory Wells

One of the proposals in the President's message to Congress of April 18 of this year is to extend the investment tax credit to expenditures on exploratory wells in the oil and gas industry. The credit against tax liability would be 7 percent of outlays on unsuccessful exploratory wells and 12 percent of outlays on successful exploratory wells. If exploration for oil and gas is to be subsidized through the tax system, the proposal is superior to raising the percentage depletion allowance (lowered from 27.5 percent to 22 percent of gross income in the Tax Reform Act of 1969), for the latter rewards production of oil and gas regardless of whether the producer is engaged in exploration for new supplies. It also rewards royalty owners, whose income is largely economic rent. The President's proposal, if enacted, would reward exploration proper, and by holding out a greater reward for successful exploration it is designed to counter the criticism that subsidizing exploration induces drilling on submarginal prospects.

But how significant an incentive would it be? According to the latest Joint Association Survey of oil and gas industry expenditures, that covering 1971, [9], total expenditures on drilling and equipping exploratory wells in the United States come to about $800 million. Seven percent of this is $56 million, equivalent to a tax deduction of $112 million. Such a deduction is only 0.7 percent of the domestic industry's $15.8 billion gross income before royalties from oil and gas production. Since a tax deduction is the equivalent of that much additional gross income, the tax credit in question would reduce the supply price of domestic oil and gas by slightly less than 0.7 percent. In short, the incentive would border on the trivial.

It may be that the government should consider a larger subsidy to oil and gas exploration, for it is possible that private industry tends to spend less on exploration than is socially optimal. For this point I am again indebted to the draft version of a study for the Energy Policy Project, by Frederick Peterson [14], cited here by permission of the author and the director of the Project. Peterson points out that in oil and gas exploration there are two externalities, one tending to restrain private exploration below the socially optimal level, the other tending to push it beyond that level. The first arises from the fact that one of the products of exploration, even unsuccessful exploration, is knowledge of value to others than the given explorer—knowledge that the given explorer cannot fully appropriate and sell for its value to others. Thus the private explorer fails to push exploration to the point where its marginal cost is equal to its marginal return to society. Society could be made better off by subsidizing private exploration to expand it to the point where that equality holds. The second externality arises from the fact that every discovery by a given explorer reduces the chances of others making a discovery, since the total number of possible discoveries is fixed by nature. On this account, the given private explorer tends to push out the margin of exploration too far from a social point of view. I am inclined to think that the former type of externality is much more important than the latter; hence my suggestion that a subsidy to oil and gas exploration may be economically justified. But even if my impression is shared by others, there remains the unanswered question of how large a subsidy would be justified.

Remaining Tax Incentives

Prior to 1970, when the Tax Reform Act of 1969 became effective, the oil and gas producing industry was allowed to take a percentage depletion deduction of 27.5 percent of gross income after royalties, calculated on a property-by-property basis and not to exceed for each property 50 percent of net income [12, pp. 8–26]. Since some costs, such as those of dry holes on nonproducing properties, are not allocable to individual properties but are otherwise deductible for tax purposes, the 50 percent of net rule does *not* mean that the effective tax rate must be at least half the nominal rate. It can be lower, and for companies actively engaged in exploration it ordinarily is. Nonetheless, the 27.5 percent figure overstates somewhat the net tax benefit on account of two factors. First, due to the 50 percent of net rule, the average depletion rate prior to 1970 was less than 27.5 percent; I have elsewhere [12, p. 21] estimated it to be about 24 percent. Second, the user of percentage depletion loses the right to take deductions for capitalized exploration and lease acquisition costs, these alternative deductions typically amounting to about 2 percent of gross income [12, p. 17]. Thus the net effective rate of depletion in excess of costs was about 22 percent of gross income prior to 1970.

In addition to percentage depletion, there was (and is) the privilege of currently expensing, rather than depreciating, the "intangible" costs of drilling and equipping productive wells, including the costs of labor, fuel, power, materials, supplies, tool rental, and repairs of equipment, which typically account for about 75 percent of total costs of drilling and equipping productive wells [12, p. 22]. The tax benefit of expensing is, of course, the saving of interest. To estimate the size of this benefit in the oil and gas industry, begin by noting that the present value of the tax saving of an expensed outlay of $100 is $50 (assuming a 50 percent tax rate), while that for an outlay depreciated according to the double-declining-balance method over 25 years at a 10 percent discount rate is approximately $26. Thus the tax benefit from expensing, $24, is the equivalent of a special deduction from gross income of $48. According to the latest Joint Association Survey of industry expenditures [9], the costs of drilling and equipping productive wells currently are about $1.6 billion, of which we assume that 75 percent, $1.2 billion, are intangible subject to expensing. Forty-eight percent of this is approximately $0.6 billion, which in turn is about 4.5 percent of the industry's gross income after royalties. Thus the sum of special tax deductions, for percentage depletion and intangibles expensing, may be expressed as 26.5 percent of gross after royalties prior to 1970.

In the Tax Reform Act of 1969 the nominal percentage depletion rate was reduced to 22 percent, and in addition a 10 percent tax was imposed on the excess of allowable depletion over the sum of $30,000 and federal income tax liability. The privilege of expensing intangibles was unchanged by the Act. With a lower nominal depletion rate, the 50 percent of net rule would have less effect in reducing the average depletion rate. A reduction of two percentage points, as contrasted with 3.5 points prior to 1970, seems reasonable. I estimate that for the typical company the 10 percent tax on preference items would in effect reduce the effective depletion rate by two points. Subtracting another two points for loss of alternative deductions, we have a net depletion benefit currently of 16 percent of gross income after royalties. Adding on 4.5 points as the equivalent of intangibles expensing, today's special tax benefits may be expressed as 20.5 percent of gross after royalties. Thus the net reduction in the Tax Reform Act was 6 percentage points.

Assuming the gross before royalty is 15 percent greater than gross after royalty, the Tax Reform Act of 1969 may be said to have raised the long-run supply price of oil and gas in the United States by 5.2 percent. If the oil import quota system had been maintained, domestic crude oil prices would presumably have increased by a similar amount. With quotas eliminated in 1973 and the free market price determined by the price of imports (and assuming the price set by the OPEC group to be independent of the depletion rate enjoyed by American companies abroad), the increase in the supply price of crude oil can only have reduced the proportion of domestic consumption supplied by domestic production.

If the remaining 20.5 percentage points of special tax benefits were eliminated, the long-run supply price of oil and gas would be increased by a further 18 percent, and there would be a proportionately larger decrease in the share of domestic consumption supplied at home. Alternatively, of course, the share could be maintained by increasing the supply price of imports by 18 percent with a sufficiently large increase in the tariff. Thus in considering further decrease in the tax benefits enjoyed by the industry, the trade-off for the American people is between prices and security of supply. It is no longer simply a matter of efficiency in the allocation of resources within the domestic economy.

Conclusion

Of the President's proposals that we have classified as having incentive effects, the strongest, and the most urgent, is the freeing of "new" gas from price regulation. It promises to equilibrate the market for gas in 1980 with a rise of about 50 percent in the relative price. The proposal to extend the investment tax credit to outlays on exploratory wells borders on the trivial. Its effect in increasing supply would be only about one-eighth of the opposite effect accomplished by the reduction of tax benefits in the Tax Reform Act of 1969. Also rather insignificant is the proposal to increase the tariff on crude oil imports by 10.5 cents/bbl to 1980. This measure will do little to check the growth of the share of domestic consumption furnished by imports, with attendant decrease in security of supply.

These negative conclusions apply, however, to only part of the President's proposals. Completing the Alaskan pipeline and tripling the rate of leasing on the outer continental shelf, which are merely permissive to private action for which adequate incentive exists, may add as much as three million barrels per day and substantial quantities of gas to domestic supplies within four years. The increase for oil would be about 25 percent of domestic supplies and, if realized, would largely negate our implied projection of a near doubling of the share of imports by 1980. In the years beyond 1980 the shape of the energy economy will undoubtedly be profoundly affected by technological change, which would be speeded up by the proposal to double the rate of energy R & D spending in the next five years—change which promises oil from shale, gas from coal, environmentally acceptable combustion of high-sulphur coal, and electric power from fast-breeder reactors. The energy crisis, while real enough for the next three or four years, may evaporate in the long run.

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Policies for Energy Research and Development*

MILTON F. SEARL AND HARRY PERRY

THIS PAPER represents an attempt to bring together two diverse points of view concerning energy R & D policies—the technical point of view and the economic point of view. The paper does not necessarily represent the views of the institutions or clients with whom the authors are affiliated, and, indeed, being a joint paper, does not fully represent the views of either author. However, both regard it as extremely important to the success of the nation's energy R & D program that there be a better understanding and closer cooperation between those concerned with the technical aspects of energy R & D programs and those concerned with the economic aspects. Economic analysis of R & D projects made by experts in a technology frequently leaves much to be desired from an economic viewpoint, whereas the analysis made by economists is frequently naive from a technical standpoint.

In this paper the objectives of energy R & D, the relationship between the economic performance of a technology and R & D expenditures on its development, and the role of the federal government are considered.

No attempt is made here to discuss the various elements of the proposed R & D programs [1] or the non-R & D alternatives to the proposed programs [2]. However, it should be noted that much of the R & D which has been proposed for funding is likely to contribute little, in a relative sense, to total energy supply before 1990 short of a government-sponsored crash program of plant construction. There is, therefore, concern lest the major emphasis on R & D distract the nation from the urgent business of formulating policies which will provide energy until the new and improved technologies, with which the R & D programs are primarily concerned, can contribute in a major way to energy supply. The nation's policymakers must not be allowed to believe that they have dealt adequately with energy supply problems once they have enacted into legislation an energy R & D program.

Introduction

The nation is about to embark on a program of energy research and development of unprecedented magnitude. At the $2 billion a year level for 10 years being proposed in Congress, the program will be of the same magnitude as the Apollo space program and will dwarf the Manhattan Project which produced the atomic bomb. Even the more modest program suggested by the President—$2 billion a year for five years—will set new records for energy R & D as well as being at the same high annual rate as the congressional program.[1] Moreover, much of the R & D initiated in the President's five-year program will be in the early stages of development at the end of five years so that the congressional and Presidential programs are more nearly alike than different.

The pressure for an increased energy R & D program has been building for some time as the scope of the nation's energy supply and energy-related environmental problems has become clearer. The cessation of Middle East oil shipments in October and November of 1973 to the United States and the unilateral escalation of oil prices by exporting nations appears to be the catalyst which will bring the program into being.

However, the history of major federal R & D expenditures has not been so favorable that a high level of economic effectiveness can be expected in the use of these funds. Nor can it automatically be assumed that these programs have environmental merit. At least two R & D programs, the SST and the breeder reactor, undertaken without sufficient independent analysis, may have courted environmental disaster and have encountered delays because of per-

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* The original draft of this paper contained a section dealing with economic analysis of R & D. Neither the available time for presentation nor the permitted length of this paper allowed inclusion of this material. The authors are now applying the suggested economic analysis methodology to specific R & D programs, on the basis of Mr. Perry's knowledge of these programs, with a view toward separate publication.

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[1] The program proposed to the President by the Chairman of the Atomic Energy Commission will call for private expenditures essentially to match federal expenditures, thus doubling the program size.

ceived dangers. Under these circumstances, economists, engineers, and scientists concerned with energy R & D should learn as much as possible from the successes and failures of the past in order to improve the effectiveness of the energy R & D efforts about to be undertaken.

Objectives of Energy R & D

The specific objectives of the nation's energy R & D programs are still rather vague. Indeed, there has been much activity in Washington in the last few months devoted to an effort to develop programs for spending the funds which are likely to be forthcoming. This is a fairly clear sign that objectives have not been adequately spelled out. The most frequently voiced objective—greater self sufficiency in energy supply—is almost meaningless from an operational standpoint. The all-important question of prices and quantities is not addressed. A key element in any energy R & D policy should be the establishment in very clear operational form of the objectives to be achieved by these expenditures. Successful research and development will require technical and commercial objectives to be established more precisely. Indeed, it may well be that the efficiency with which all but basic research is carried out is closely related to how well defined are the program objectives.

The time period in which the objective is to be achieved is an important part of the objective. It affects the appropriate magnitude and pattern of expenditures. Sequential R & D is likely to result in a minimum cost program. Parallel development efforts, if adequately funded, are likely to result in earlier achievement of technical objectives but generally at substantially higher costs. *A priori* it is not possible to say which is most economic—in part it depends upon the size of the benefits resulting from earlier achievement of the objectives and in part on the increased costs that are required.

In view of the vagueness of program objectives so far enunciated, it is useful to examine the many and varied objectives which have been used in the past to justify energy R & D programs and will no doubt be used for various components of the present program. The following list is not all-inclusive, and the objectives are far from independent:

(1) Reduce the cost of energy
(2) Provide flexibility of supply
(3) Provide customers with a choice of energy systems
(4) Promote competition
(5) Expand knowledge
(6) Increase energy availability
(7) Exploit a resource
(8) Promote self sufficiency
(9) Promote environmental quality
(10) Provide a product for foreign markets.

Of those objectives listed above, only reducing the cost of energy has major economic dimensions. The other objectives involve economic considerations of lesser and varying degree. In addition, support for R & D in general and energy R & D in particular has been justified to:

(11) Provide employment for R & D personnel displaced by major shifts in other government R & D programs
(12) Seek to continue work at agencies and institutions adversely affected by shifting national priorities.

The optimization of energy policies given such a diverse set of objectives with unspecified degrees of importance and whose relative importance tends to fluctuate over time would clearly constitute a mathematical miracle. A major first task for analysts and policy makers is to sort out and consolidate these objectives and to attempt to provide a logical, stable weighting system. Some of the objectives on the list are liable to prove of dubious economic merit. Moreover, for most of the objectives there are non-R & D methods of achieving the same objective which should be weighed against the R & D option. The appropriate policies for implementing an R & D program depend in a major way on the relative weight given to these objectives.

Characteristics and Limitations of Energy R & D

We turn now to a discussion of some of the characteristics and limitations of energy R & D. Research and development projects in general, and certainly in the energy field, are said to involve the following characteristics:

(1) Long lead times
(2) Great uncertainty
(3) High cost.

However, as subsequent analysis will indicate, these characteristics may be as much the result of vague or improperly specified objectives and performance requirements as inherent characteristics of energy R & D. At some point in time, a given technology becomes scientifically feasible. Considering broad categories (e.g., fission, breeders, fusion), all technologies likely to receive any significant funding in the next ten years are now scientifically feasible. However, the performance of many is poor (i.e., the cost per unit of output is high). Research and development is expected to improve performance from a technical standpoint and to reduce unit cost of output (e.g., mills per kilowatt hour). However, for any given process or specific technology there is a practical limit to the improvement in performance within any reasonable time frame which can be brought about by R & D [3].[2]

The work of the senior author, while at Resources for the Future, Inc., leads to the conclusion that if we accept the proposition that there is a technical performance limit for a specific process or version of a technology, as scientists and engineers tell us, then there is in a very real sense also a limit to the improvement in economic performance which can be brought about by R & D on the technology. The existence of limits to the economic performance of a technology tends to be obscured by the fact that as a technology emerges from the R & D stage, its economic performance—that is, the unit cost of output—may continue to decrease through time due to unit and industry scale effects, due to that class of improvements generally characterized as learning curve phenomena, and due to competitive forces which may temporarily reduce the market price of output below normal as companies struggle to establish market share. Nevertheless, the concept of an economic performance limit, as well as a technical performance limit that can be achieved through R & D for a process or version of a technology, may provide a very useful source of insight into policies appropriate for managing R & D.

The view of a limit to economic performance is not the common view. There appears to be a widespread belief that sufficient R & D can lower the cost of output from any technology or process indefinitely. This idea is patently false. The idea finds popular expression in such views as, "if we can put a man on the moon," why can't we solve the energy shortage, or reduce the cost of housing to reasonable levels, or solve the transportation problem. The difference is that in "putting the man on the moon" the technical problems are solved in a setting in which there is limited concern about the economic performance of the technology, to say nothing of the R & D costs. When economic tests must be met, such approaches are not likely to produce an economically viable technology. Indeed, it is only because "man on the moon" projects can ignore to a considerable extent the economic, institutional, and regulatory problems which plague commercial developments and focus on the technical aspects that they can accomplish their goals on what appear to be reasonable time schedules.

Economic Performance as a Function of R & D

Mathematically, in its simplest form the idealized relationship between the economic performance of a technology and R & D costs can be visualized as the positive branch of a hyperbola which is asymptotic to a line parallel to the x axis. In this context, economic performance refers to the cost or price of a unit of output which could be achieved with the technology under commercial conditions of manufacture and utilization.

Algebraically, the form is

$$C = a + \frac{b}{x}$$

where C is economic performance measured as the cost of a unit of output, a is the cost asymptote, b is a constant, and x is cumulative R & D expenditures (see Fig. 1).

Although the particular equation specified may not be typical, the precise form is not very important to the conclusions here as long as we are willing to postulate positive returns to R & D over a sufficiently large R & D expenditure (i.e., that R & D does not decrease performance except possibly for small increments) and admit that there is a practical performance limit for any specified process or specific technical approach.[3]

The rate at which economic performance, C, improves as a function of cumulative R & D can

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[2] The definition of a process or technology is crucial to the discussion of both technical and economic limits. For example, incandescent and fluorescent lights represent different technologies just as do vacuum tubes and transistors.

[3] A curve which shows only slight improvement in economic performance in the early stages of R & D expenditures, then drops sharply, and finally becomes asymptotic to a line parallel to the x axis would also be a logical formulation for this relationship.

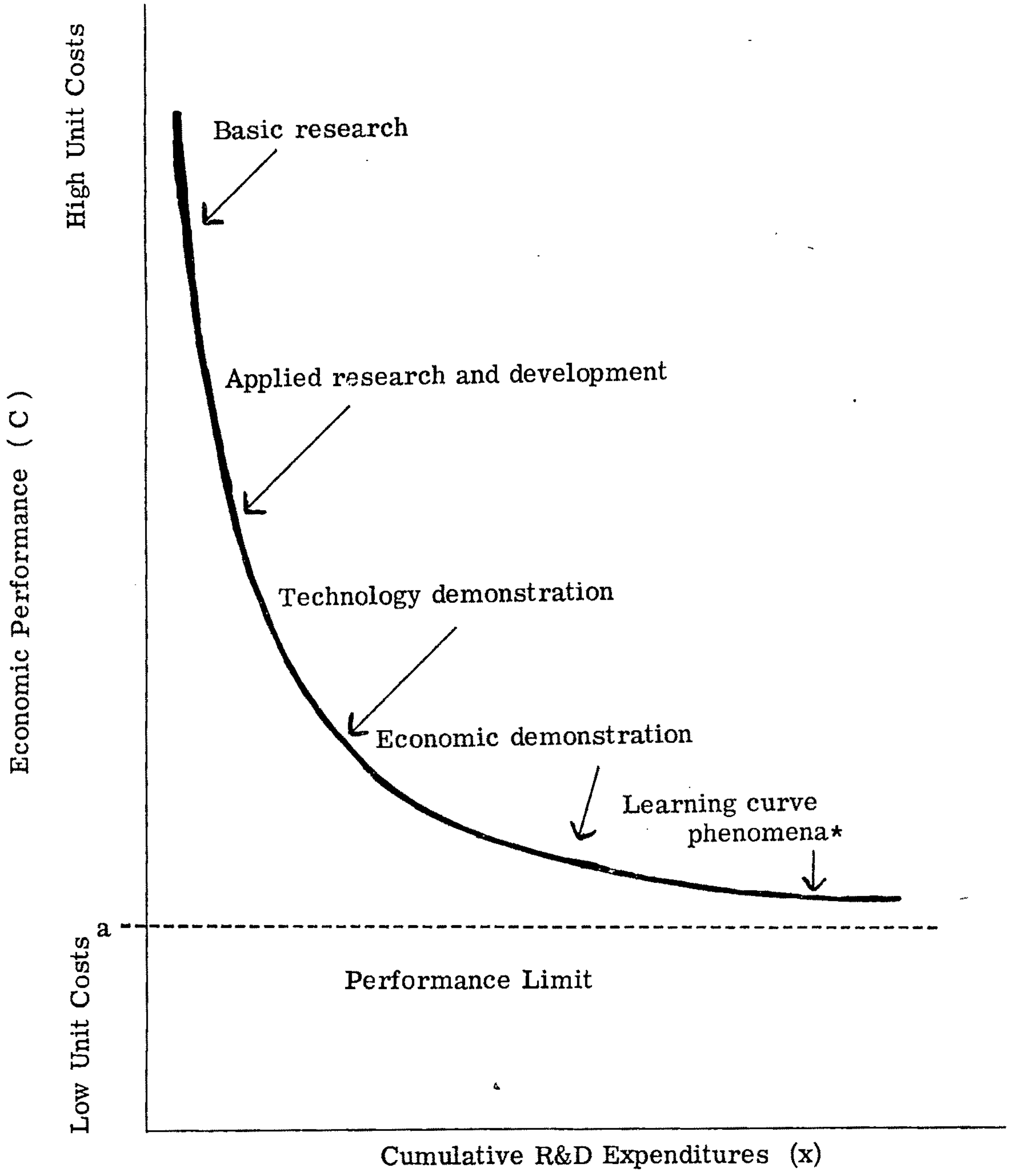

Figure 1. **Idealized relationship between economic performance and R & D expenditures for a specific process or technology**

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* If the horizontal axis were cumulative R & D expenditures plus cumulative cash flow outflow for production, this area could certainly be considered one of learning.

be shown by taking the derivative of C with respect to cumulative R & D. The derivative is

$$\frac{-dC}{dx} = \frac{+b}{x^2}.$$

Economic performance improves only as the square of cumulative R & D expenditures. If the curve relating economic performance and R & D expenditures has a different shape, economic performance could improve faster (i.e., unit cost of output could decline faster) than the square of cumulative discoveries along some portion of the curve. However, given a performance limit, an immediate consequence of such a curve shape is that unit costs of output must decline less rapidly than the square of cumulative R & D expenditures in other regions of the curve.

Further refinements to the conceptual relationship between economic performance and R & D are possible. A refined version of the curve could add explicit factors for the effectiveness of R & D, for scaling possibilities of commercial units, and for economy of scale at the industry level. In the present $C = a + \frac{b}{x}$ formulation, these factors are implicit in the definition of cost.

Time can be introduced into the economic performance–cumulative R & D expenditure relationship by specifying R & D expenditures as a function of time and substituting in the relationship between economic performance and cumulative R & D. It must be kept in mind, however, that rapid changes in the time rate of R & D expenditure may interact with R & D efficiency.

The concept of R & D efficiency is not well defined at the moment. Clearly inadequate basic research, poorly designed experiments, overlapping experiments, staffing and funding at less than some "critical mass," overstaffing, administrative and budgetary delays, and inadequately qualified personnel can all contribute to inefficiency. However, care must be used in making any blanket condemnation of such factors. They may be optimizing factors in another dimension. For example, overlapping experiments and duplication may save time. Even though they increase immediate R & D costs, they may bring on benefits at an earlier date.

It was pointed out above that R & D is generally regarded as being characterized by long lead times, great uncertainty, and high cost. And it was suggested that these characteristics might, in part, be due to lack of precision in R & D objectives. If the general form of the relationship between economic performance and R & D suggested here is correct, then these characteristics may also result from the adoption of economic and technical performance characteristics which are unrealistic rather than being inherent characteristics of R & D.

The form of the functional relationship between economic performance and cumulative R & D suggests two policy points: First, that in the early stages of attempting to reach an objective, such as vastly improved coal liquefaction technology, a variety of R & D approaches may well be supported because economic performance increases rapidly as a function of cumulative R & D at first and because it is very difficult to tell in the early stages of R & D how fast the performance curve will plunge and how far it will go; scientists and engineers have been advocating such a multiple approach for years. Second, because further improvement in economic performance—that is, decrease in unit costs comes only as the square of cumulative R & D expenditures—some sort of sudden death mechanism needs to be established to terminate R & D projects—a view quite contrary to that held by many scientists and engineers. Much of the inefficiency in R & D may come not as a result of funding too many R & D projects in the early stages but rather of continuing too many projects into the expensive demonstration and beyond stage where further improvements are likely to be costly to obtain (due to the cumulative R & D squared effect) and marginal as far as improvements in economic performance are concerned. If we devise measures to terminate projects efficiently, as we probably can, these measures should include provisions to protect professionally and financially the people involved.

Representation of Alternatives on the Economic Performance—R & D Diagram

Figure 1 did not attempt to show whether or not R & D is expected to result in a unit cost of output that is economic (i.e., whether or not the cost of output from another source or another technology, possibly also requiring R & D, lies below the asymptote for a given process or technical approach). If the asymptote is too high, no amount of R & D expenditures on that specific technology will suffice to render output "economic." This case is illustrated in Figure 2. Here alternative *a* might represent the production of synthetic crude oil from coal while *b* represents production of shale oil. (There is no agreement among experts that this is indeed the coal liquids-shale oil relationship.)

In Figure 3, alternative *a* might represent gasification of coal to produce pipeline quality gas, while alternative *c* might represent production of natural gas. Here unit costs of alternative *c* are initially below the best performance of

Comparison of Alternatives

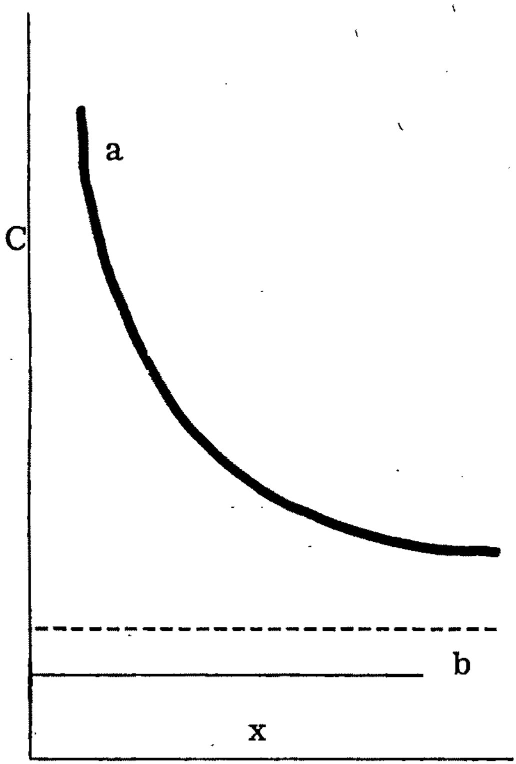

Figure 2

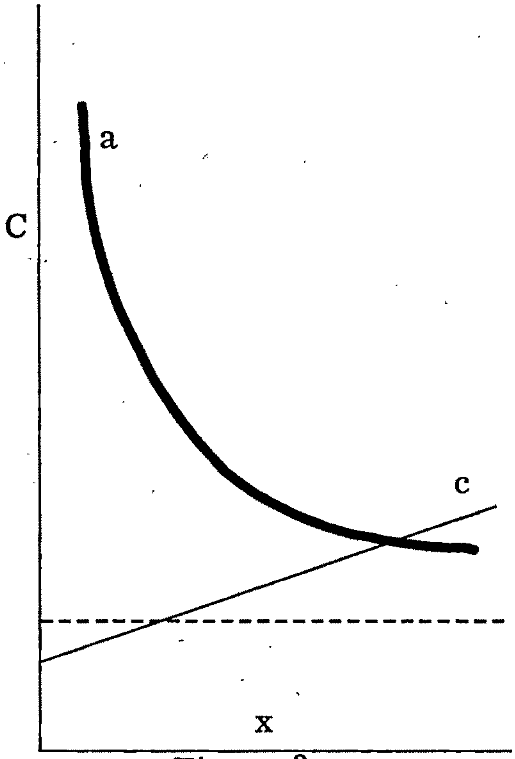

Figure 3

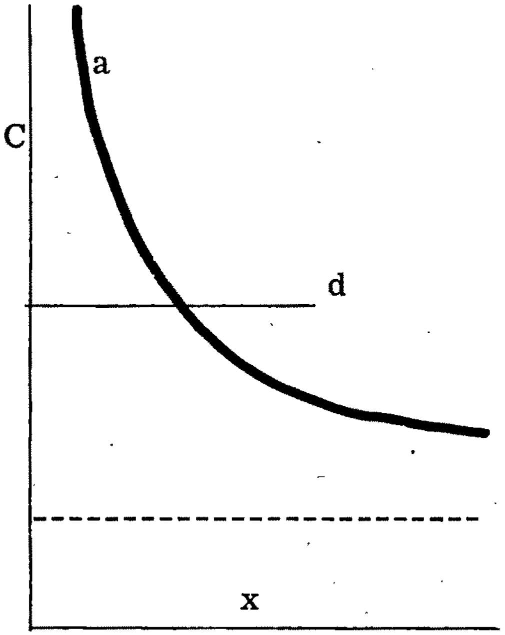

Figure 4

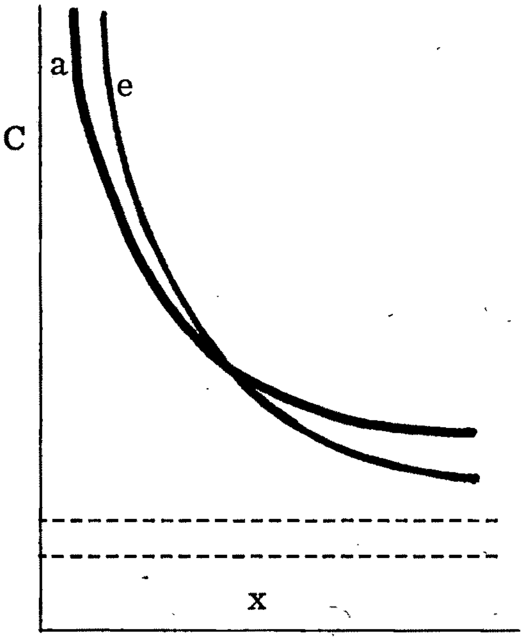

Figure 5

alternative *a* but are expected to rise above those of *a*. The economic problem in this case is one of timing—how fast will the costs of *c* rise, and what is the appropriate rate of R & D expenditure on alternative *a* to improve economic performance?

Figure 4 shows a desirable case where the best alternative to R & D program *a* is alternative *d* whose unit costs are rather clearly above the performance limit which R & D is expected to reach.

In Figure 5 the case for two competing technologies simultaneously undergoing R & D is shown. If the two curves level out at about the same area of economic performance, decision between them can be very difficult. In such cases there may be a commercial role for both technologies. (Boiling water and pressurized water reactors may be a historical example of this.) Fortunately, from society's standpoint, if performance levels are nearly the same (and noneconomic factors comparable) and a choice is made, the consequences of a "wrong" choice are not great.

The vertical scale for these figures is economic performance—dollars per unit of output. The horizontal scales will depend upon the specific comparisons. Separate scales may be required for each curve or preferably both curves may be related to time and time used for the horizontal axis.

The Role of Government R & D

The major increases in energy R & D spending in the coming decade will apparently come from the government although dramatic increases in such spending are being made by industry, industry-financed associations, and nonprofit groups. In view of the large financial role to be played by the government, it is appropriate to inquire as to the proper role of government in energy R & D. Such an inquiry is immediately handicapped by the aforementioned vagueness of government R & D objectives in the energy area.

A crucial question is whether or not it is the function of the government to seek to reduce energy costs through R & D. Some economists, including the senior author, have never been convinced of the cardinal importance of low-cost energy to a mature economy such as that of the United States. This leads to the suggestion that three stages of R & D be considered—basic and applied research, technology demonstration, and economic demonstration or commercialization. In the case of basic and applied research and technology demonstration, the objectives may be considered to be of a technical nature. It may well be that government R & D objectives should be technical rather than commercial. Strictly technical objectives, reasonably set, probably can be met without long lead times, great uncertainty, or excessive costs. Operationally this point may be thought of as carrying through the technology demonstration phase. By way of illustration, consider oil shale technology for which at least one process now appears to be at the technology demonstration stage. In fact, with recent rises in foreign and domestic crude oil prices, the cost of alternatives may even now have placed oil shale in the economic demonstration or commercial range.

The cost and performance history of the first large plants demonstrating a new technology in recent years has been such as to constitute a major barrier in the introduction of new energy technology. The firms which build the first one or two plants are likely to suffer economic loss, even though the technology is basically sound and potentially commercial. Thus government expenditures for demonstration may be justified. However, it should not automatically be assumed that demonstration should follow successful completion of basic and applied R & D. Each of the three stages—basic and applied R & D, technology demonstration, and commercialization—should be the subject of separate and explicit decisions. No matter how successful basic and applied research has been, conditions regarding other sources of supply and R & D developments in other technologies will have affected the logic of going into the technology demonstration phase. Similarly, there should not be an assumption that economic demonstration should automatically follow successful technology demonstration. Here again external conditions may have changed sufficiently that even though a demonstration plant meets its technical objectives, commercialization is no longer justified.

Again using shale oil as an example, the government might well do whatever is necessary for the demonstration of shale oil technology in order that this large source of energy may be readily available if needed. However, once reasonable levels of technical performance are achieved, the government should then no longer participate as far as further demonstration is concerned regardless of whether shale oil is competitive with other sources or not. Actually, market and institutional factors are far more important in whether or not oil shale becomes commercial than the technical uncertainties.

A firm distinction between the development and demonstration of technology and commercialization of that technology should also be welcome from the environmental standpoint. As a result of our nuclear development strategy, government development and demonstration of a technology has now come to mean in the minds of many that the technology will be used regardless of the consequences. It may well be that breaking this link can help increase public confidence in science and technology.

If technology is at a point where decreases in unit cost of output are heavily dependent upon scale-up in unit size, then the potential cost savings are not very great, and the uncertainties of scale-up and the operating problems which can only be found after the plant is on-line are very likely to affect the economics of the operation adversely. In order to have reasonable prospects of commercial success, the expected costs of a new technology should be such that large scale-ups are not necessary to demonstrate the technology. The frequent view that anything can be made economic if only the unit size is large enough is an inheritance of dubious value from our nuclear experience, where only by major extrapolations in scale could nuclear be expected to be competitive. Many of the concerns about safety and environmental effects and some of the performance problems of nuclear plants appear to be closely related to the major jumps in unit size necessary to give expectations of competitive status.

As indicated above, it seems reasonable to us for the government to sponsor some basic and applied research on noneconomic grounds. In some cases it may even be reasonable for the government to carry work through technology demonstration even without expectations that successful technology demonstration would lead to economic demonstration (e.g., it would have been appropriate some years back, and may still be appropriate, for the government to have sponsored a plant demonstrating oil shale technology on the grounds of ensuring the availability of the technology without attempting commercialization). However, when a program, such as the nuclear power program, is undertaken by the government with a view to commercial benefits, serious problems are likely to ensue. The agencies and congressional committees concerned are likely to come to the view that they have a mission to make the technology economic (competitive) "at any cost." If there are economic performance limits to a technology, then it may be very difficult or impossible to achieve commercial viability, and expenditures continue indefinitely in a vain attempt to do so. This can result in a strong temptation to subsidize the technology in one way or another and possibly to take short cuts on matters of safety and environmental protection. In the view of the senior author it is generally a mistake for the government to attempt to commercialize a technology. The conditions governing whether or not a product or service becomes commercial are extremely complex. Even our major corporations with the best available economic and marketing advice frequently make mistakes in this area. It is, in the senior author's opinion, quite presumptuous for the government to believe that it can determine the relative competitiveness of various energy R & D outcomes as well as the status of the conventional sources of energy supply. This is why he much prefers that government not try to push R & D into the area where the economic performance curve has flattened out but rather confine itself to predominantly technical objectives and allow the market to determine what is commercial. The coauthor sympathizes with concerns regarding government attempts at commercialization, but based on his experience believes that difficult problems of technology transfer are involved which may require more government activity directed at commercialization than might otherwise seem necessary.

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Dynamic Demand Analyses for Gasoline and Residential Electricity*

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THE EVENTS of this last year have made consumers everywhere aware of the need for an adjustment in energy consumption patterns. In the 1960's the price of energy appears to have fallen in real terms and as a result the growth of most forms of energy consumption accelerated. Until recently most energy resources —excluding natural gas where the price was kept down by regulation—were in a buyers' market. The emphasis was on sales promotion. In electricity, for instance, utilities offered special incentives to increase usage, such as favorable offers on appliances or free light bulbs, while continuing to rely on their long-standing practice of lower average prices for large consumption. The gasoline market was also soft, as appears from such various types of marketing actions as games and free gifts to increase sales. Excess capacity in refining strengthened the hand of independent marketers, whose emergence often led to price wars. In buying new cars most consumers paid little attention to gasoline mileage.

Today, however, the problem is not to increase energy sales but to decrease them. This has raised the question as to whether market mechanisms will be able to adjust supply and demand to each other. Already there are signs that the market may not be given a chance. Public opinion polls show that a majority of the public feel gasoline rationing is needed, and one city, Los Angeles, has ordered all households to reduce electricity consumption by 10 percent or have their power turned off. Clearly there is no widespread confidence in the efficacy of higher prices in curtailing demand, although the price increases themselves are criticized on distributional grounds. Greater knowledge of the effect of prices is needed not only for short-term domestic policy, but also for anticipating developments in the world petroleum market, where a producer cartel is now firmly in charge.

In this paper we present results on the demand for gasoline and residential electricity, the two largest items in the consumer's energy budget These demand functions are estimated using pooled time series data from different states This disaggregated approach was selected because regional variations in prices and consumption patterns provide valuable information for disentangling the effects of price changes. The data are fitted to dynamic demand functions of the flow-adjustment type; this specification corrects for the lack of adequate data on changes in the characteristics of the capital stocks involved.

Past experience with demand analysis for narrowly specified consumption goods has brought out the importance of dynamic elements, particularly habit formation. The response of consumers to a change in income or prices is generally spread out over time; complete adjustmen often takes years, and it is therefore useful to distinguish between short-run and long-run elasticities. In the case of habit formation, which has been found to prevail in the vast majority of nondurable goods and services, the short-run elasticity is less than the long-run elasticity (in absolute value). The opposite is true of durable goods, which are said to exhibit stock adjustment. While energy resources are by their very nature nondurable, stock adjustment is also relevant to the energy problem. Almost without exception energy resources are complementary with durable goods such as automobiles, electrica equipment or home heaters.

In principle a full analysis of the demand for energy should therefore cover the associated equipment as well as the energy resources themselves. However, such a combined analysis raises serious problems of statistical technique which have not yet been resolved. In fact, an adequate analysis of the energy resources by themselves is difficult enough because of other complications that are especially marked in them. Thus both gasoline and electric power display considerably more regional price variation than do most items of consumption. An analysis based on nationwide time series, which has become the standard approach to demand analysis, cannot do justice to such variation and is unsatisfactory to that ex

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tent. Such analysis may also be distorted by interregional shifts in population; the migration towards the "sun states," for instance, has obvious implications for energy consumption. As did previous investigators such as Fisher & Kaysen [2] and Balestra & Nerlove [1], we have therefore relied on time series for individual states, which adds significantly to the work involved but also appears to produce results of greater relevance and robustness.

The Model

In the short run the individual's demand for energy is primarily determined by his stock of energy-using capital goods. Some authors, in fact, have assumed that this is the only factor influencing demand.[1] In our analysis, however, we reject this assumption as inconsistent with accepted theories of demand. Instead, we employ a less restrictive assumption underlying the flow-adjustment model of demand, described in Houthakker and Taylor [5]. In such models the stock of energy-using capital is assumed to be fixed over the short run, and the utilization of it is assumed to be a function of normal economic influences. In such a case a classical adjustment model of demand can be used. In particular we assume that there is a desired demand q^*_{it} for energy by individuals in state i at time t. This demand is made a function of income and price:

$$q^*_{it} = f(p_{it}, y_{it}). \tag{1}$$

For simplicity we assume that $f(\ )$ is log-linear:[2]

$$q^*_{it} = \alpha\, p_{it}^{\gamma}\, y_{it}^{\beta}. \tag{2}$$

Further, a very simple adjustment process is assumed:

$$q_{it}/q_{i,t-1} = (q^*_{it}/q_{it-1})^{\theta}, \tag{3}$$

where $0 < \theta < 1$. In such a case the estimating equation becomes

$$\ln q_{it} = \theta \ln \alpha + \theta\gamma \ln p_{it} + \theta\beta \ln y_{it} + (1-\theta) \ln q_{i,t-1}. \tag{4}$$

It should be noted that this model assumes the utilization rates for all energy-using types of capital to be the same, regardless of vintage and other characteristics. Such an assumption is clearly undesirable. As pointed out earlier, it would be better to incorporate the utilization of the capital stock directly in the demand equation and then to derive a model which separates the utilization and the investment process into two equations. Pending the development of such a model, which could probably be estimated today using available data, we have adopted the flow adjustment model as the most useful specification.

The Energy Resources Examined

The demand for the two energy resources is examined here at the regional level where individual observation on consumption is a state average. This high level of disaggregation is useful because there is more variation in prices and consumption of gasoline and electricity within states than in the country as a whole. Further, different climatic conditions, population movements, and other regional differences serve to vitiate an aggregate model.

Electricity and gasoline also provide an interesting contrast due to the different way they are priced. In particular gasoline is sold at a constant price per unit while the price of a unit of electricity depends upon the amount consumed. In fact, electric power is the outstanding example of a commodity whose unit price depends on the quantity consumed. In the U. S. electric power for residential use is generally sold at block rates. These typically involve a minimum monthly bill (usually entitling the consumer to a certain number of kilowatt hours) and successive "blocks" in each of which the unit price is lower. Originally the blocks were related to different uses (lighting, cooking, water heating, etc.), but this link is no longer of importance.

The average price per kwh is therefore a declining function of consumption and so, up to a point, is the marginal price. Most economists with an interest in electricity demand have recognized that according to economic theory it is the marginal price, not the average price, that determines the amount consumed.[3] From a statistical point of view the determination of marginal prices is difficult, however, and this is one of the main reasons why aggregate analyses of the demand for electric power have generally not been successful.

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[1] This is the assumption behind the work of Balestra and Nerlove [1].

[2] We have also experimented with linear functions, but on balance the logarithmic specification appears to be somewhat better.

[3] The average price is important primarily in deciding whether to become an electricity customer at all. Since in recent years virtually all households in the U. S. have been connected, this factor need no longer be considered in demand analysis for electricity; it is still of some relevance to natural gas.

Data Used in the Analysis

Except for the electricity price data, the data used here are collected from standard sources and modified only by very simple adjustments. Therefore discussion of these data is relegated to the Appendix of this paper. However, the electricity price data used in the analysis require some explanation. As mentioned in the preceding section, a correct analysis of electricity demand should be based on marginal prices, which are much harder to obtain from statistical sources than average prices. The most convenient source of price data is *Typical Electric Bills,* an annual publication of the Federal Power Commission. For all localities in the country with 2,500 or more people, it provides the monthly residential bill when consumption is at a rate of 100, 250, or 500 kwh per month (for some recent years there are also typical bills for 750 and 1000 kwh, but these have not been used here). Because of their standardized form these figures are invaluable in comparing the rates charged by different suppliers, but the marginal rates, which are part of the underlying tariff schedules, do not appear explicitly. The marginal rates in the interval between 100 and 250 kwh can be estimated by subtracting the 100 kwh bill from the 250 kwh bill and dividing by 150. Similarly the marginal rate in the 250–500 interval can be estimated by subtracting the 250 kwh bill from the 500 kwh bill and dividing by 250, while the marginal rate in the 100 to 500 interval is obtained by subtracting the 500 kwh bill from the 100 kwh bill and dividing by 400. These estimates are clearly not exact, but they are probably close enough.[4]

Because of the large number of communities represented in *Typical Electric Bills,* it was not feasible to apply this method to each of them individually; rather, the typical bills for 100, 250, and 500 kwh were first averaged from a sample of cities for each state. The sample included all cities with a population over 100,000 and every tenth locality with a population below that limit. The same localities were used for every year.[5] Because of data limitations, this calculation could only be made for the 12 years from 1960 through 1971, and for the 48 conterminous states (excluding the District of Columbia). From the average state bills thus calculated the marginal price was estimated by the procedure just derived. A few apparent anomalies in the published data, resulting in implausibly low marginal prices, were corrected *ad hoc*. The two marginal prices—one for the 100–250 kwh range and one for the 250–500 kwh range—were then deflated by the (nationwide) deflator for personal consumption expenditure from the National Accounts. This deflator was used to convert all series from nominal to real terms.

Estimation Procedure

The estimation technique used in this study is the error component technique (often referred to as a variance component technique) first developed by Balestra and Nerlove [1] and programmed by Alan Freiden. The need for a technique of this sort is created because the flow adjustment model contains a lagged dependent variable, and in such circumstances ordinary least-squares methods produce biased estimates of the parameters. Further, the bias of the adjustment coefficient is known to be toward unity implying that calculations using ordinary least-squares estimates could indicate a larger price increase required to achieve a given conservation goal than is actually needed. This was thought to be a sufficiently serious complication that better methods of estimating dynamic demand functions were sought. The possible alternatives considered were instrumental variables and error components.

For the analysis in this paper the error components technique was chosen. There were several reasons for the choice. First, according to simulation studies by Nerlove [7, 8], estimates obtained using the error components technique generally produce estimates which are closer to the true parameters than those obtained using other techniques. Second, error components provided a method for taking account of between-state fluctuations while ordinary least squares and instrumental variables did not. Third, and most critical, error components techniques are known to provide the best estimate (although not the best unbiased estimate) of the adjustment parameter.[6]

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[4] A more elaborate procedure was used in an unpublished Ph.D. thesis by Halvorsen [3].

[5] For some recent years average state bills are also available from *Typical Electric Bills,* but since data consistency is essential to the estimation of marginal prices, they have not been used here.

[6] Mount, Chapman, and Tyrrell [6] rejected this technique on the grounds that it would not give a better fit. This is not a valid reason. Error components techniques are appropriate for models of the kind considered here

Statistical Results

The logarithmic flow adjustment model was fitted to the electricity data for the interval from 1961 to 1971 using annual observations for 48 states. The same model was fitted to quarterly data on gasoline consumption for the interval 1963 to 1972 for 48 states and the District of Columbia. The difference in frequency makes the comparison of the results somewhat difficult, although not impossible.[7] Thus the number of observations was 528 for electricity and 1960 for gasoline. The results are as follows (with standard errors in parentheses).

Gasoline:

$$\ln(q_{it}) = \underset{(.032)}{.593} - \underset{(.013)}{.075}\ln(p_{it}) + \underset{(.017)}{.303}\ln(y_{it}) + \underset{(.019)}{.696}\ln(q_{i,t-1})$$

$$R^2 = .92$$

The quarterly consumption of gasoline (on a seasonally adjusted basis) has a short term price elasticity of .075 where price is defined as the ratio of the price at the pump, including all taxes, for major branded regular gasoline deflated by the overall price index for all consumption. The short term income elasticity is .30 where income is defined as average real per capita disposable in the particular state for a given quarter. All the estimates are statistically significant by the usual criteria. The long term price and income elasticities are .24 and .98.

Electricity:

As noted above, three marginal prices were computed. The statistical results are given below, again with standard errors in parentheses.

(Marginal price between 100 and 500 kwh)

$$\ln(q_{it}) = \underset{(.029)}{.072} - \underset{(.020)}{.089}\ln(p_{it}) + \underset{(.026)}{.143}\ln(y_{it}) + \underset{(.015)}{.913}\ln(q_{t-1})$$

$$R^2 = .986$$

(Marginal price between 100 and 250 kwh)

$$\ln(q_{it}) = \underset{(.030)}{.062} - \underset{(.023)}{.094}\ln(p_{it}) + \underset{(.026)}{.127}\ln(y_{it}) + \underset{(.015)}{.921}\ln(q_{i,t-1})$$

$$R^2 = .986$$

(Marginal price between 250 and 500 kwh)

$$\ln(q_{it}) = \underset{(.029)}{.104} - \underset{(.014)}{.029}\ln(p_{it}) + \underset{(.026)}{.145}\ln(y_{it}) + \underset{(.014)}{.934}\ln(q_{i,t-1})$$

$$R^2 = .986$$

The results are almost identical for all three sets of price data except that the price elasticities are higher for the 100–250 and 100–500 kwh data than they are for the 250–500 kwh data. The reason for this difference may be that the prices calculated from 100–250 kwh as well as the prices from 100–500 kwh are not really marginal prices but include some of the fixed charge to customers. As Houthakker [4] and Verleger [9] have shown, this tends to bias the estimated price elasticity towards one. Further research is needed to clarify this point, on which the data from *Typical Electric Bills* do not allow us to reach a clear decision. For instance, to determine whether the mean price difference between 100 and 250 kwh adequately reflects the marginal price in that interval (or indeed beyond that interval), we would have to know how many pricing blocks appear in residential tariffs for this quantity of consumption. If there were only one block, the calculated price is clearly the marginal price. If, however, there were 10, and the change in price from highest to lowest was large relative to the price charged for the 101st kwh, then the calculated price would not be an accurate indicator of the marginal price. This knowledge would be required for a large number of the utilities in the United States before we could reach any definitive conclusion.

As a final point we note that the long run income and price elasticities are 1.6 and —1.0 when the 100–500 kwh price data are used, 1.6 and —1.2 when the 100–250 kwh marginal price data are used, and 2.2 and —.45 when the 250 to 500 kwh price data are used.

Comparison of Estimation Methods

Since the results presented so far were all derived by the error component technique, it is of some interest to know what estimates would be

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as well as by Mount, *et al.*, because they provide a more consistent estimate of the coefficient on the lagged dependent variable and consequently of the other parameters too. This advantage is achieved, however, at the expense of a *lower* fit.

[7] The lack of quarterly data at a state level on the consumption of electricity is the reason for the difference in frequencies. Earlier we had estimated the demand for gasoline at an annual frequency for a longer period of observation, with results roughly consistent with those presented here.

produced by other methods of estimation. The following table compares the error component (*EC*) results with those obtained by two varieties of ordinary least-squares (OLS), one using a common intercept for all states and the other using a different intercept for each state to allow for differences in urbanization, climate, and availability of public transportation. A comparison is also made with an instrumental variables estimate (*IV*) which also used a different estimate for each state. The instrumental variables used were lagged incomes, lagged prices, and population.

The most interesting observation that can be drawn from Table 1 is that the error component method produces a regression that differs very little from ordinary least-squares with state intercepts. This observation, of course, applies only to this particular set of data, but it may be regarded as reassuring in view of the robustness of least-squares estimators. Ordinary least-squares with a common intercept, however, does not provide satisfactory results, as can be seen particularly from the coefficient of the lagged dependent variable which is close to one. The instrumental variables estimates also do not show up too well because of relatively large standard errors, illustrating the well-known inefficiency of this method.

Regional Analysis

The results presented in this paper reflect the estimation of the demand functions over all states without any attempt to differentiate by region. The model was, however, fitted to a number of different groupings of states. This regional analysis has not yet led to any conclusive results, but it should be noted that in both electricity and gasoline a classification into nine census regions does not appear to be useful. Very little homogeneity is apparent between the states when grouped in this manner. There is somewhat more of a pattern in an alternative grouping by percent urbanization as shown in Tables 2 and 3.

Table 1. Gasoline: results from different estimation methods*

	Price	Income	Lagged consumption	R^2
OLS	—.023	.0031	.9894	.976
(common intercept)	(.012)	(.0039)	(.0037)	
OLS	—.081	.341	.6595	.979
(49 intercepts)	(.013)	(.018)	(.0171)	
IV	—.121	.284	.7207	.900
(49 intercepts)	(.016)	(.036)	(.0352)	
EC	—.075	.303	.6957	.929
	(.013)	(.017)	(.0164)	

* Standard errors in parentheses.

Table 2. Gasoline: estimates for groups of states ranked by degree of urbanization

	Intercept	Price	Income	Lagged Consumption	R^2
First 10 states*	.358	—.039	.204	.812	.935
	(.063)	(.029)	(.034)	(.031)	
Second 10 states	.457	—.080	.243	.774	.966
	(.061)	(.020)	(.032)	(.030)	
Third 10 states	.915	—.099	.445	.554	.919
	(.085)	(.028)	(.042)	(.041)	
Fourth 10 states	.950	—.105	.427	.574	.919
	(.093)	(.032)	(.045)	(.041)	
Last 9 states**	.589	+.058	.233	.750	.933
	(.086)	(.036)	(.037)	(.036)	

* These are the most urbanized states; the District of Columbia is treated as a state.

** These are the least urbanized states.

The first four rows of Table 2 suggest that for both price and income the short-run elasticities are smaller in absolute magnitude for the highly urbanized than for the less urbanized states. Since the coefficient of the lagged dependent variable has the opposite tendency, however, the long-run elasticities are more similar. The fifth

Table 3. Residential electricity: estimates for groups of states ranked by degree of urbanization

	Constant	Price*	Income	Lagged Consumption	R^2
First 9 states	.158	—.047	.332	.872	.992
	(.057)	(.034)	(.068)	(.034)	
Second 10 states	.041	—.095	.139	.921	.990
	(.051)	(.030)	(.049)	(.026)	
Third 10 states	.146	—.020	.116	.934	.988
	(.068)	(.045)	(.059)	(.034)	
Fourth 10 states	—.007	—.092	.074	.951	.977
	(.084)	(.049)	(.056)	(.036)	
Last 9 states	.194	.173	.254	.817	.988
	(.089)	(.067)	(.064)	(.042)	

* Based on the price differential between 100 and 500 kwh.

row, covering the least urbanized states, is disfigured by a positive estimate for the price elasticity and generally does not fit in with the rest of the table. It is possible that in this group much gasoline is used for agricultural purposes and that the explanatory variables may therefore not be entirely appropriate.

Similar results emerge when electricity demand is examined for states grouped by percent urbanization. In this case, however, the income elasticity is larger for the most urbanized states. Further, the coefficient on the lagged dependent variable is smaller for the most urbanized states and increases as urbanization decreases. Unlike gasoline, though, the price elasticities exhibit no apparent pattern. In fact the price coefficients for the four groups of most urbanized states are all within two standard deviations of —.05 and thus probably not different from each other in a statistical sense. Finally we note that the results for the least urbanized states are distorted by a positive price coefficient, as they were with gasoline. This possibly can be attributed to the problem of classifying agricultural establishments in the residential or commercial category. As was the case for gasoline, a different model may be required.

Simulation with the Gasoline Model[8]

One of the reasons we chose to estimate a model of quarterly demand for gasoline was to compare a simulation of the first three quarters of 1973 against the actual data. This test was sought because tentative results had indicated a fairly large price elasticity of demand and some skepticism had been expressed by those who had examined the first draft of our study. There were two basic criticisms of the results. The first criticism was that our price elasticity was unplausibly large since gasoline is only a small fraction of the total cost of owning and operating a car. Secondly, the model did not take account of significant changes designed to reduce air pollution that had been introduced into new cars since 1969; these latter changes were thought to be very important. Both of these factors would, in 1973, have the same effect on the ability of the model to predict gasoline consumption—that is, they would cause the model to underpredict gasoline demand. This underprediction would be the result of the increased percentage of late model vehicles with their associated air pollution devices and resulting poor fuel consumption characteristics and also of our price elasticity if indeed it was too large. Since prices of gasoline rose by 3 to 4¢ per gallon during the spring of 1973, the price elasticity was being put to an immediate test.

Simulation of the model for these three quarters produced just the opposite results from those expected by these critics. Although the model underpredicted first quarter consumption by .2 percent, it overpredicted second quarter consumption by 1.4 percent and overpredicted third quarter consumption by 1.3 percent (after seasonal adjustments).[9] Two explanations are offered for the error. The first is that the publicity about gasoline shortages reached a peak during the second quarter of 1973. This publicity may have had a psychological effect on consumption though it would seem that very few motorists were actually unable to buy as much as they wanted at that time.

A more appealing explanation, however, can be found in the changing role of the independent gasoline dealer during the first half of 1973. It is well-known that many independent dealers were forced to close for lack of gasoline supplies. However, a possibly more important change, involving the price differential between independents and major branded stations, has attracted less attention. Those independents still able to get gasoline have been forced to increase their prices to the level charged by major branded dealers, or even higher, because they are no longer able to purchase so-called surplus gasoline at lower costs. This change is, unfortunately, not picked up in our data, which are based only on prices charged by major-brand service stations. Thus, in addition to the 4¢ price increase, some states may in effect have experienced another 4¢ increase due to the increase in prices charged by independents.

Although we cannot make adequate allowance for this data problem, it does not appear that our price elasticity is too large. The argument that gasoline is a small part of the cost of owning and operating a car is of questionable relevance. Much of this cost consists of depreciation, insurance, and license fees and is therefore largely independent of utilization. In fact some calculations suggest that gasoline accounts for as much as 47 percent of the variable cost of car operation.

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[8] We were unable to simulate the electricity model for 1972 because the data on prices for 1972 are not yet available.

[9] See [10, Ch. II] for a more complete explanation of the qualitative differences.

Conclusion

In this paper we have shown that the growth in electricity and gasoline demand can be attributed to rising incomes and falling relative prices during the 1960's. The role of falling prices in this period has often gone unrecognized. Preliminary indications from simulations for the first two quarters in 1973 indicate that rising prices are already reducing demand substantially. Thus we conclude that the arguments made for energy rationing by many politicians and some economists are unfounded. The market mechanism by itself appears to be capable of bringing about the necessary adjustments in demand. Consequently there are also limits to the price increases that a producer cartel can exact.

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APPENDIX

Gasoline Consumption

There are two sources of gasoline consumption data. They are the American Petroleum Institute and the Federal Highway Administration. The data published by the Federal Highway Administration are thought to be more accurate, but for this paper the API data were used because the publication lag on the FHWA data is over one year. The API series used is called Motor Gasoline Consumption. This series includes all consumption except gasoline sold for aviation purposes and gasoline sold to the Federal Government.

Electricity Consumption

Total electric utility industry sales to residential customers data are taken from the Edison Electric Institute's *Statistical Year Book* for various years. These data under-represent total residential consumption because some apartments purchase electricity under other tariffs.

Gasoline Price Data

Platt's 55 city price survey data on the price of regular gasoline including all taxes were used. These data represent only a sample of major brand gasoline stations and are thus probably upward biased. However, no better data were available. The price data are published in the American Petroleum Institute's *Petroleum Facts and Figures*.

Personal Income Data

Per capita personal income data on a regional basis are published by the Regional Economics Division of the Bureau of Economic Analysis, U. S. Department of Commerce. This agency does not, however, regularly publish disposable income on a regional basis. Thus, to obtain estimates of disposable income on a regional basis, the published personal income data were deflated by the ratio of aggregate national personal income to national disposable personal income. This procedure has the effect of preserving the distribution of personal income between states for each time period but allows for changes in the distribution over time.

Population

Data are taken from the U. S. Census Bureau.

Price Deflators

The deflator for total personal consumption expenditures published by the U. S. Department of Commerce, Bureau of Economic Analysis, was used.

Electricity Consumption: Supply Requirements, Demand Elasticity and Rate Design

John W. Wilson

Residential Power Consumption

In 1970 the residential use of electricity in large cities in the United States averaged 6,367 kwh per household [5].[1] This average annual volume represented an increase in residential electricity consumption of about 45 percent per residential unit as compared with consumption five years earlier. Adding to this population growth and a parallel increase in the number of households, there was a *total* increase in residential electricity demand of nearly 60 percent between 1965 and 1970.

Previous work indicates that residential demand for electricity has generally been price elastic in the long run.[2] The empirical evidence presented below is consistent with that finding. However, it is argued that it does not necessarily follow that rate increases will have a price elastic demand restraining influence in the future, nor is it clear that rate inversion (i.e., charging relatively more for incremental supplies so as to discourage large volume usage) is allocatively efficient.

During the last 20 years, residential electricity sales in the United States have grown at an average rate of over 9 percent per year. From 1950 to 1970 the population of the U. S. increased by about 35 percent and per capita income increased by almost 170 percent. At the same time, however, residential electricity consumption rose by more than 500 percent. It is estimated that during this period about three-fourths of the growth in residential electricity use was attributable to rising consumption per household, while only about one-fourth was due to an increase in the number of homes served. On the average, the typical American home, which used less than 2,000 kilowatt hours (kwh) of electricity in 1950, consumed over 7,000 kwh in 1970.

Part of this increase is attributable to the widespread introduction of new residential energy uses such as air conditioners, television sets, clothes dryers, and dishwashers. In addition, further increases were inspired by shifts to electricity from other fuels as, for example, in space heating, water heating, and cooking. Over this same 20-year period, personal income rose substantially while the price of electricity fell. These two factors are often cited as the dual economic causes of historic increases in residential electricity demand.

Some household electricity requirements, such as lighting, have increased relatively little over the past two decades. Others, such as air conditioning (a new energy use) and space heating (a substitute use), have grown enormously. As a consequence, lighting, which accounted for nearly 30 percent of residential electric power consumption in 1950, now represents only about 10 percent of household demands. At the same time space heating and air conditioning, which together account for over 30 percent of current residential use, amounted to only about 5 percent 20 years ago.

The typical annual electric energy requirements for major household electric appliances and equipment are listed in Table 1. As shown there, electric space heating is, by far, the largest component of the total power demand in a modern all-electric home. Water heating and air conditioning come next, followed by food freezers, refrigerators, and clothes dryers.

The total amount of energy used for each of these purposes depends, of course, upon the number of households which actually have the specified appliances. For example, space heating still accounts for less total residential electricity consumption than refrigeration because less than 10 percent of American homes are electrically heated, while virtually all residences are equipped with one or more refrigerators.

Table 2 shows the percentage of homes in the U. S. which were equipped with each of these major appliances in 1960 and 1970. While there have been substantial increases during the last decade, the table also indicates that there is ample opportunity for future electricity demand growth if saturation levels continue to increase over the next 10 years. Particularly in view of apparent fossil fuel shortages, a rising trend is not inconceivable. For example, some electric

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[1] This refers to cities of 50,000 population or more.

[2] See, for example, [1, 2, 3, 9, 11, and 12].

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Table 1. Typical electric energy requirements

Type of Equipment	Kwh Per Year
Electric Space Heating	16,003
Electric Water Heating	4,219
Electric Range	1,175
Clothes Washer	103
Electric Clothes Dryer	993
Food Freezer (15 cu. ft.)	1,195
(Frostless)	1,761
Central Air Conditioning	3,600
Window Air Conditioner	1,389
Dishwasher	363
Television (B&W)	362
(Color)	502
Refrigerator (14 cu. ft.)	1,137
(Frostless)	1,829

Source: Edison Electric Institute.

utilities have indicated that as of the last quarter of 1973 more than 70 percent of the new housing units under construction in their service areas will be electrically heated. If this very recent development continues, residential demand increases will be substantial indeed.

Non-residential Power Consumption

Non-residential electricity consumption has grown at an annual rate of nearly 7 percent during the past decade (1962–1972). At present it amounts to about two-thirds of total electricity demand (residential is about one-third). While manufacturing industries account for only about 30 percent of total earnings in the U. S. economy, they account for 65 percent of non-residential electric power consumption. About one-sixth of total industrial consumption is self-generated. The remainder is purchased from electric utilities and government agencies.

Table 2. Residential electric equipment (percentage of housing units with specified equipment)

	U. S.	
	1960	1970
Electric Space Heating	1.8%	7.7%
Electric Water Heating	20.4%	25.4%
Electric Cooking	30.8%	40.6%
Clothes Washer	73.7%	71.1%
Electric Clothes Dryer	11.9%	29.4%
Food Freezer*	18.4%	28.2%
Dishwasher	—	18.9%
Two or more T.V. sets*	9.9%	28.7%
Air Conditioning	12.4%	35.7%
Central Air Conditioning	1.9%	10.7%
Two or more room air conditioners	2.9%	7.2%
One room air conditioner	7.6%	17.8%

Source: U. S. Department of Commerce, Bureau of the Census, *Census of Housing* (1960 and 1970).

* Saturation levels are close to 100 percent for refrigerators and one or more T.V. sets.

Electricity consumption and the total energy electricity equivalent per dollar of value added by manufacturing are shown in Table 3. As

Table 3. Industrial energy requirements

SIC Code	Industry Description	Electricity[a]	Total Energy[b]
2011	Meat packing plants	1.13	10.41
2013	Sausages and prepared meats	.87	6.35
2015	Poultry dressing plants	1.47	8.20
2021	Creamery butter	1.92	41.74
2022	Cheese, natural and processed	1.46	13.08
2023	Condensed and evaporated milk	.89	21.18
2026	Fluid milk	1.07	7.99
2032	Canned specialties	.51	7.58
2033	Canned fruits and vegetables	.61	7.57
2037	Frozen fruits and vegetables	1.82	8.19
2041	Flour and other grain mill products	2.50	9.32
2042	Prepared feeds for animals and fowls	1.27	11.20
2046	Web corn milling	1.40	50.09
2051	Bread, cake, and related products	.52	5.04
2052	Cookies and crackers	.54	1.06
2061	Raw cane sugar	.78	23.54
2062	Cane sugar refining	.22	29.69
2063	Beet sugar	.52	101.18
2071	Confectionery products	.71	3.11
2072	Chocolate and cocoa products	1.37	9.52
2073	Chewing gum	.40	1.70
2082	Malt liquors	21	2.49
2083	Malt	4.13	52.98
2085	Distilled liquor except brandy	.29	10.52
2086	Bottled and canned soft drinks	.35	4.76
2092	Soybean oil mills	3.98	47.71
2094	Animal and marine fats and oils	1.76	39.36
2096	Shortening and cooking oils	.13	21.23
2095	Roasted coffee	.36	3.46
2099	Food preparations	.61	6.35
2111	Cigarettes	.26	2.03
2121	Cigars	.48	1.26
2131	Chewing and smoking tobacco	.27	2.69
2141	Tobacco stemming and redrying	1.56	10.58
2211	Weaving mills, cotton	4.23	10.52
2221	Weaving mills, synthetic	3.80	8.83
2231	Weaving mills, wool	1.92	14.81
2241	Narrow fabric mills	1.13	6.99
2251	Women's hosiery	1.28	
2253	Knit outerwear mills	1.19	
2256	Knit fabric mills	1.42	10.60
2261	Finishing plants, cotton	1.72	38.97
2262	Finishing plants, synthetic	1.89	30.70
2269	Finishing plants, n.e.c.	1.92	19.38
2281	Yarn mills, except wool	4.84	8.32
2282	Throwing and winding mills	3.35	10.04
2283	Wool yarn mills	2.43	8.30
2284	Thread mills	3.08	12.20
2295	Coated fabrics, not rubberized	1.15	8.66
2296	Tire cord and fabric	5.27	10.10
2411	Logging camps and contractors	.18	19.43
2421	Sawmills and planing mills	2.11	11.97
2426	Hardwood dimension and flooring	(N.A.)	1.53
2431	Millwork plants	.76	2.81
2432	Veneer and plywood	2.31	9.00
2491	Wood preserving	.70	23.23
2499	Wood products n.e.c.	1.85	13.47
2511	Wood household furniture	.79	3.60
2611	Pulpmills	5.57	66.94
2621	Papermills, except buildings	5.42	63.21
2631	Paperboard mills	3.51	83.47
2661	Building paper and board mills	7.39	60.43
2641	Paper coating and glazing	.95	5.86
2653	Corrugated and solid fiber boxes	.88	7.32
2711	Newspapers	.41	1.08

Table 3, continued

2721	Periodicals	.13	.48
2731	Book publishing	.08	.35
2732	Book printing	.59	2.01
2741	Miscellaneous publishing	.19	.58
2751	Printing, except lithographic	.74	2.88
2752	Printing, lithographic	.49	1.93
2812	Alkalines and chlorine	22.18	139.03
2813	Industrial gases	16.90	44.45
2815	Cyclic intermediates and crudes	3.53	41.41
2816	Inorganic pigments	2.13	41.16
2818	Industrial organic chemicals n.e.c.	3.74	69.22
2819	Industrial inorganic chemicals n.e.c.	19.20	77.22
2821	Plastics materials and resins	2.67	21.21
2822	Synthetic rubber	3.88	39.10
2823	Cellulosic manmade fibers	.93	60.51
2824	Organic fibers, noncellulosic	2.03	21.35
2831	Biological products	.87	4.63
2833	Medicinals and botanicals	1.30	17.28
2834	Pharmaceutical preparations	.40	2.45
2841	Soap and other detergents	.33	4.19
2851	Paints and allied products	.47	4.28
2861	Gum and wood chemicals	1.29	29.40
2871	Fertilizers	4.96	30.59
2872	Fertilizers mixing only	.72	10.57
2891	Adhesives and gelatin	.70	17.24
2892	Explosives	1.67	42.46
2895	Carbon black	3.61	50.70
2899	Chemical preparations n.e.c.	.68	16.97
2911	Petroleum refining	3.68	83.14
2951	Paving mixtures and blocks	1.50	54.92
2952	Asphalt felts and coatings	.12	33.78
3011	Tires and inner tubes	1.47	11.24
3069	Fabricated rubber products n.e.c.	1.29	10.03
3079	Miscellaneous plastics products	2.50	7.47
3211	Flat glass	2.34	37.00
3221	Glass containers	2.77	41.08
3229	Pressed and blown glass n.e.c.	1.81	28.57
3231	Products of purchased glass	.91	8.59
3241	Cement hydraulic	9.23	169.30
3251	Brick and structural tile	10.75	119.68
3253	Ceramic wall and floor tile	1.21	20.54
3255	Clay refractories	1.79	59.56
3259	Structural clay products n.e.c.	1.77	84.27
3261	Vitreous plumbing fixtures	1.10	27.19
3271	Concrete block and brick	3.04	21.41
3272	Other concrete products	.51	9.29
3273	Ready mixed concrete	.48	17.38
3274	Lime	5.11	230.39
3275	Gypsum products	2.92	40.25
3281	Cut stone and stone products	1.49	10.21
3291	Abrasive products	1.65	6.95
3292	Asbestos products	1.80	11.94
3295	Minerals ground or treated	2.24	38.58
3296	Mineral wool	3.25	43.08
3297	Nonclay refractories	2.27	35.95
3312	Blast furnaces and steel mills	3.91	30.55
3313	Electrometallurgical products	40.64	105.98
3315	Steel wire and related products	2.26	9.46
3316	Cold finishing of steel shapes	2.82	10.41
3317	Steel pipe and tubes	1.42	5.11
3321	Gray iron foundries	1.82	18.09
3322	Malleable iron foundries	2.63	21.79
3323	Steel foundries	2.82	14.39
3331	Primary copper	3.27	49.96
3332	Primary lead	2.35	59.40
3333	Primary zinc	12.49	145.06
3334	Primary aluminum	51.68	133.47
3339	Primary nonferrous metals n.e.c.	17.89	37.81
3341	Secondary nonferrous metals	1.35	18.83
3351	Copper rolling and drawing	2.39	12.58
3352	Aluminum rolling and drawing	4.11	20.89
3356	Rolling and drawing n.e.c.	2.74	12.73
3357	Nonferrous wire drawing etc.	1.42	5.36
3361	Aluminum castings	1.45	12.76
3362	Brass, bronze, copper castings	1.11	9.24
3369	Nonferrous castings	1.30	7.59
3391	Iron and steel forgings	1.23	25.56
3392	Nonferrous forgings	2.34	20.41
3399	Primary metal products n.e.c.	2.30	22.00
3411	Metal cans	.87	5.04
3423	Hand and edge tools, n.e.c.	.53	4.21
3429	Hardware, n.e.c.	.76	3.78
3431	Metal sanitary ware	1.26	15.63
3433	Heating equipment except electrical	.71	4.37
3441	Fabricated structural steel	.65	4.63
3442	Metal doors sash and trim	.74	4.40
3443	Fabricated platework (boiler shops)	.73	4.90
3444	Sheet metalwork	.51	3.94
3451	Screw machine products	.62	2.01
3452	Bolts, nuts, rivets and washers	.77	3.49
3461	Metal stampings	1.07	3.58
3471	Plating and polishing	1.56	15.76
3479	Metal coating and allied services	.85	12.28
3481	Miscellaneous fabricated wire products	.67	3.40
3494	Valves and pipe fittings	.72	4.34
3499	Fabricated metals products, n.e.c.	.77	2.02
3511	Steam engines and turbines	.68	7.81
3519	Internal combustion engines n.e.c.	.81	3.35
3522	Farm machinery	.51	4.85
3531	Construction machinery	.82	4.04
3533	Oilfield machinery	.94	3.79
3541	Machine tools metal cutting types	.49	2.17
3544	Special dies, tools, jigs, and fixtures	.51	2.35
3545	Machine tool accessories	.63	3.73
3548	Metalworking machinery n.e.c.	.62	3.46
3552	Textile machinery	.72	4.14
3559	Special industrial machinery n.e.c.	.55	2.55
3561	Pumps and compressors	.53	3.33
3562	Ball and roller bearings	1.10	5.16
3566	Power transmission equipment	.65	3.40
3569	General industrial machinery n.e.c.	.56	2.94
3573	Electronic computing equipment	.47	1.07
3585	Refrigeration machinery	.61	3.22
3599	Miscellaneous machinery, except electrical	.81	3.40
3621	Motors and generators	.76	3.12
3624	Carbon and graphite products	8.70	24.43
3632	Household refrigerators and freezers	1.05	6.89
3642	Lighting fixtures	.71	4.07
3661	Telephone and telegraph apparatus	.52	3.08
3662	Radio and TV communications equipment	.55	.79
3679	Electronic components n.e.c.	.82	1.58
3691	Storage batteries	2.04	7.65
3699	Electrical equipment n.e.c.	3.54	12.88
3711	Motor vehicles	.78	4.58
3714	Motor vehicles parts and accessories	1.18	5.55
3721	Aircraft	.64	1.79
3722	Aircraft engines and parts	.90	2.93
3729	Aircraft equipment n.e.c.	.77	2.47
3731	Shipbuilding and repairing	.81	2.87
3742	Railroad and street cars	.98	6.73
3821	Mechanical measuring devices	.41	1.63
3861	Photographic equipment and supplies	.31	3.39
3941	Games and toys	.60	2.26
3949	Sporting and athletic goods n.e.c.	.65	3.03
3993	Signs and advertising displays	.42	3.14
1925	Complete guided missiles	.55	11.89
1929	Ammunition except for small arms, n.e.c.	1.33	5.33

Source: U. S. Department of Commerce, Bureau of the Census, *1967 Census of Manufactures*.

[a] Purchased kilowatt-hours per dollar of value added by manufacturing.

[b] Represents the quantity of electric energy and the kilowatt-hour equivalent for all fuels used for heat and power per dollar of value added by manufacturing.

indicated there, electricity and total energy intensiveness of production functions vary substantially from one industry to another. Moreover, to the extent that electricity and fossil fuels are substitutable for each other, the potential for electric power growth in most industries is vast indeed. Historically the relatively high cost of electricity as compared with other fuels has restrained industrial demand growth. In the future it is not inconceivable that higher fossil fuel prices, limited supply availability and environmental pressures may serve to increase the electricity intensiveness of some industrial production functions.

Total residential and non-residential electricity sales from 1962–1972 are shown in Table 4.

Table 4. U. S. electric energy sales (1962–1972)

	U. S. (billions of kwh) Residential	Non-Residential
1962	226.4	549.7
1963	241.7	589.1
1964	262.0	628.3
1965	281.0	672.4
1966	306.6	732.4
1967	331.5	775.5
1968	367.7	834.6
1969	407.9	899.3
1970	447.8	943.6
1971	479.1	987.4
1972	511.4	1,066.3
Average Annual Growth Rate	8.5%	6.8%
1990*	1,749.3	3,318.4
Projected Rate	7.1%	6.5%

Source: *Electric World,* 3/15/73 and 9/15/73.
* As projected by *Electric World* 9/15/73.

While most projections indicate that this historic rate of growth may be expected to taper off in the future, the extent of any such decline depends greatly upon future economic growth rates, the success of energy conservation efforts, and whether, in the face of apparent fossil fuel shortages, nuclear power will be called upon to fulfill general energy needs which were heretofore met through less costly alternatives.

Price Elasticity

In the midst of surging electricity demands, regulatory agencies have recently been urged to use price as a discretionary tool to restrain power production requirements.[3] This prescription is premised on the findings of recent studies which indicate that in the long run the demand for electricity has been highly sensitive to price.[4] The new statistical results reported below are further empirical evidence of a significant historic price-quantity relationship. They do not, however, show a strong short-run price impact.

Residential demand

An ordinary least squares log-linear regression model was used, covering 280 U. S. cities which had 20,000 or more residential housing units in 1970. The following variables were specified:

Q = quantity of electricity per household in 1970 (kwh per year).
ΔQ = $Q \div$ quantity of electricity per household in 1965.
Y = median household income in 1970 ($ per year).
ΔY = $Y \div$ median household income in 1960.
H = number of occupied residential housing units in 1970.
ΔH = $H \div$ number of occupied units in 1960.
S = summer temperature (average for July).
W = winter temperature (average for January).
D = population density (persons per square mile).
$\frac{E}{G}$ = typical electric bill for 1,000 kwh per month $\div$ the statewide average price of natural gas.

The statistical results were as follows:

$$
\begin{array}{lllll}
Q = 3{,}437 & +\ .088Y & +\ .109\Delta Y & -\ .017H & \\
\quad (2.367) & (.125) & (.263) & (.020) & \\
\text{partial } r^2 = & .00 & .00 & .00 & \\
+\ .332\Delta H & +\ 2.030S & +\ .188W & -\ .189D & \\
(.103) & (.257) & (.052) & (.026) & \\
.04 & .19 & .02 & .16 & \\
-\ .406E/G & & & & \\
(.062) & & & & \\
.14 & & & & \\
\quad R^2 = .544 & & & &
\end{array}
$$

and

$$
\begin{array}{lllll}
\Delta Q = -3.700 & -\ .048Y & +\ .419\Delta Y & -\ .018H & \\
\quad (.757) & (.040) & (.084) & (.006) & \\
\text{partial } r^2 = & .08 & .08 & .03 & \\
+\ .069\Delta H & +\ .650S & +\ .018W & +\ .009D & \\
(.033) & (.082) & (.017) & (.008) & \\
.02 & .19 & .00 & .00 & \\
+\ .005E/G & & & & \\
(.020) & & & & \\
.00 & & & & \\
\quad R^2 = .355 & & & &
\end{array}
$$

Interestingly, the relative price of electricity was statistically significant with respect to average consumption, but insignificant with respect to recent demand increases, thus underscoring the long-run nature of the price-quantity relationship. Markets with high summer temperatures had both high consumption levels and relatively high rates of demand growth, reflecting the pervasive impact of growing air conditioning requirements. Densely populated residential markets had significantly lower average total demands, probably due to the prevalence of smaller dwelling units, but demand growth in these markets was proportionally equal to demand growth in less densely populated cities. In addition, recent demand growth seems to have been related to income growth, particularly in relatively low income markets. Finally, both average demand and demand growth were somewhat greater where a relatively larger portion of the total housing units were constructed during the most recent decade, indicating that new housing units tend to consume greater amounts of electric power.

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[3] See, for example, [4, 6, 7, 8, and 10].

[4] See [1, 2, 3, 9, 11, and 12].

One possible exception to the finding that short-run demand levels have been unresponsive to price variations is in consumption by the very largest residential users—i.e., those with total electric homes, including electric space heating. An ordinary least squares regression model covering 123 utility companies produced the following results:

$$\begin{array}{lcccc} C = & 16{,}233 & -\ 67.07P & -\ 239.9W & +\ 311.1S \\ & (5.551) & (16.65) & (37.9) & (75.0) \\ \text{partial } r^2 = & & .12 & .25 & .13 \\ & & & & R^2 = .297 \end{array}$$

where C = average annual consumption per "all-electric" customer (Kwh),
P = marginal price per kwh for large volume space heating customers (¢),

and W and S are defined in the same manner as above. Because this computation is restricted to all-electric customers, the results indicate that these customers may indeed vary their consumption somewhat in response to price variations.

Industrial demand

Using 1962 and 1963 industrial electric power consumption data published for SMSA's in the 1963 Census of Manufactures, cross sectional log-linear regressions of the following type were constructed for each of fifteen SIC two-digit industry groups:

$$\text{kwh}_{xn} = K + a_1\,VA_{xn} + a_2P_{xn}$$

where kwh_{xn} is annual electricity consumption by two-digit industry group x in SMSA n, K is the constant quantity intercept, VA_{xn} is the value added by manufacturing by group x in area n, P_{xn} is the relevant average price of electricity, and the a's are the derived regression coefficients.

The results are summarized in Table 5. Five values are given there for each industry group. N is the number of observations; E is the estimated price elasticity coefficient (a_2 in the above equation); R_1^2 is the determination coefficient (explained variation) with VA_{xn} as the only independent variable; and R_2^2 is the determination coefficient with the price of electricity (P_{xn}) added to the equation. The partial r^2 value for P_{xn} is also reported in the table. Of the 15 industry groups studied, the price of electricity appears to be an insignificant determinant of consumption in only three—printing, rubber and plastics, and petroleum and coal products. In the other 12 cases P_{xn} is always significant at the 99 percent confidence limit.

Table 5

Two-Digit Industry	N	E*	partial r^2	R_1^2	R_2^2
Chemicals	31	2.23	.781	.616	.859
Primary Metals	31	1.51	.889	.737	.945
Stone Clay & Glass	31	1.08	.559	.640	.753
Paper Products	31	1.48	.725	.581	.801
Food Products	31	1.09	.652	.887	.935
Electrical Mach.	31	1.76	.794	.802	.927
Textiles	14	1.22	.606	.810	.927
Lumber Products	20	1.64	.825	.865	.977
Machinery	60	1.16	.627	.885	.957
Transp. Equip.	48	1.01	.335	.887	.925
Leather Prod.	19	0.76	.428	.938	.965
Furniture	31	0.97	.260	.878	.910
Printing	51	—	.110	.891	.903
Rubber & Plastics	30	—	.047	.953	.956
Petrol. & Coal Prod	27	—	.154	.928	.940

* Price Elasticity Values given only where significant at the 99 percent confidence limit.

Our primary concern here is with the price elasticity value and the extent to which the price variable adds to explained variation. It is particularly interesting to note that the price variable adds substantially to explained variation, and demand is price elastic in those industries that use an exceptionally large amount of power per unit of output. The industry groups are ranked in Table 6 according to electricity usage. It is noteworthy how well this conforms to price elasticity—those industries with the most power-intensive production techniques being the most highly sensitive to price variation. The single most obvious exception is electrical machinery, which ranks low in power consumption but high in elasticity.

The primary conclusions drawn from Tables 5 and 6 are that demand for electricity is often price elastic at the two-digit industry group level and that price is an increasingly important determinant of electricity consumption in those industries with large power requirements.

A check on the statistical results

It was assumed in the analysis above that the regression equations for the two-digit industry groups are unrelated. That is, the disturbances across equations are assumed to be uncorrelated—there being no obvious *a priori* reasons for believing that the dependent variables specified are determined by regional characteristics other than the price of electricity or value added by manufacturing.

This assumption can be tested and, if it is incorrect, the coefficient estimates can be improved through the application of a simultaneous estimating technique developed by Arnold Zellner in 1962 [14].

Zellner's joint estimating model is quite similar to a three-stage least squares estimating procedure. Letting primes stand for transpose, the basic equation is

$$b = (X'V^{-1}X)^{-1}\,(X'V^{-1}Y)$$

where X is a matrix of determinants:

$$X = \begin{bmatrix} X_a & 0 & \cdot & \cdot & \cdot & 0 \\ 0 & X_b & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \cdot & \cdot & \cdot & X_M \end{bmatrix}$$

$$X_a = \begin{bmatrix} 1 & VA_{a_1} & P_{a_1} \\ 1 & VA_{a_2} & P_{a_2} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ 1 & VA_{a_N} & P_{a_N} \end{bmatrix}$$

$$X_M = \begin{bmatrix} 1 & VA_{M_1} & P_{M_1} \\ 1 & VA_{M_2} & P_{M_2} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ 1 & VA_{M_N} & P_{M_N} \end{bmatrix} ;$$

V^{-1} is the inverse of the Kronecker product of the indentity matrix and the matrix of random error terms (i.e., residuals):

$$V^{-1} = (U'\,U)^{-1} \otimes \mathrm{I}$$

$$U = \begin{bmatrix} u_{1.a} & u_{1.b} & \cdot & \cdot & \cdot & u_{1.M} \\ u_{2.a} & u_{2.b} & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ u_{N.a} & u_{N.b} & \cdot & \cdot & \cdot & u_{N.M} \end{bmatrix}$$

$$I = \begin{bmatrix} 1 & 0 & 0 & \cdot & \cdot & \cdot & 0 \\ 0 & 1 & 0 & \cdot & \cdot & \cdot & 0 \\ 0 & 0 & 1 & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & 0 & \cdot & \cdot & \cdot & 1 \end{bmatrix} ;$$

and Y is the dependent variable matrix:

$$Y = \begin{bmatrix} Y_a \\ Y_b \\ \cdot \\ \cdot \\ \cdot \\ Y_M \end{bmatrix}$$

Table 6

Two-digit industry	Price Elasticity	ΔR^2	Kwh/V.A.
Chemicals	2.23	.242	8.39
Primary Metals	1.51	.208	6.34
Petroleum & Coal Prod.	*	*	5.44
Paper & Related Prod.	1.48	.220	5.28
Textile Products	1.22	.117	2.65
Stone Clay & Glass Prod.	1.08	.113	2.61
Rubber & Plastics	*	*	1.69
Lumber Products	1.64	.112	1.48
Food Products	1.09	.048	1.01
Transp. Equip.	1.01	.038	0.90
Elec. Machinery	1.76	.125	0.78
Machinery	1.16	.072	0.67
Furniture Products	0.97	.032	0.62
Leather Products	0.76	.027	0.49
Printing	*	*	0.38

* P_{x_N} was not statistically significant.

$$Y_a = \begin{bmatrix} K_{a_1} \\ K_{a_2} \\ \cdot \\ \cdot \\ \cdot \\ K_{a_N} \end{bmatrix}$$

$$Y_M = \begin{bmatrix} K_{M_1} \\ K_{M_2} \\ \cdot \\ \cdot \\ \cdot \\ K_{M_N} \end{bmatrix}$$

A restriction imposed on the employment of this technique is that each of the industry groups included in the analysis ($a, b, \ldots, M$) must encompass the same cross section of metropolitan areas ($1, 2, \ldots, N$).

A sufficient number of corresponding observations was obtained for six of the 15 two-digit industry groups considered above. The results of the simultaneous regression technique are contrasted with those obtained using ordinary least squares in Table 7. In each case the first equation is obtained using OLS and the second using Zellner's joint method. The results are very nearly the same. Most significantly, the price elasticities are still greater than unity and all variables retain statistical significance at the .001 confidence limit. Thus the Zellner technique serves to confirm the results obtained using ordinary least squares. Geographic patterns are adequately accounted for by the independent variables specified.

Inverted Electric Rate Structures

Electric power rates are generally structured so that large power users pay less per kwh than small users, and most consumers are able to obtain marginal units at prices below their average rate. Recently, it has been argued that because electricity demand is price elastic, consumption could be restrained substantially by inverting these prevailing rate structures so that the incremental units purchased by large volume consumers cost more rather than less.[5]

Empirical evidence, however, challenges this concept on grounds that inverted rates would be allocatively inefficient because the true cost function is downward sloping as consumption per customer rises.[6]

Table 7*

Industry		R^2
Chemicals	$K_1 = -\ .486 + .963V_1 - 2.23P_1$	.859
	$K_2 = -\ .589 + .999V_2 - 2.32P_2$	
Primary Metals	$K_1 = -\ .162 + .837V_1 - 1.51P_1$	.945
	$K_2 = -\ .409 + .875V_2 - 1.46P_2$	
Stone, Clay & Glass	$K_1 = -\ .590 + .800V_1 - 1.08P_1$	.753
	$K_2 = -\ .580 + .846V_2 - 1.31P_2$	
Paper Products	$K_1 = -\ .063 + .775V_1 - 1.48P_1$	.725
	$K_2 = -\ .226 + .797V_2 - 1.43P_2$	
Food Products	$K_1 = -1.664 + .957V_1 - 1.09P_1$	.935
	$K_2 = -1.718 + .986V_2 - 1.19P_2$	
Electric Machinery	$K_1 = -1.150 + .990V_1 - 1.76P_1$	.794
	$K_2 = -1.429 + 1.002V_2 - 1.57P_2$	

* All variables are statistically significant at the .001 confidence limit. $K = \log_{10}$Kwh; $V = \log_{10}$V.A.; $P = \log_{10}$ of average price per Kwh.

For example, letting

C = total operating cost per kwh (mills)
R = average annual residential consumption (kwh)
I = average annual non-residential consumption (kwh)
S = system size (number of customers)
G = system growth (net plant in 1969 ÷ net plant in 1959)
N = nuclear generation as a percentage of total generation
H = hydroelectric generation as a percentage of total generation
P = purchased power as a percentage of total generation
F = fuel expense per kwh (mills)

and using data for the 60 largest investor-owned electric utilities in the U. S., we obtain the following regressions:

$$\begin{array}{l} C_{69} = 16.384 - .241(10^{-3})R - .253(10^{-4})I \\ \qquad t = \qquad 1.60 \qquad\qquad\qquad 6.79 \\ \qquad + .719(10^{-6})S - .708(10^{-2})G + 25.05N \\ \qquad\quad 1.51 \qquad\qquad\quad 1.03 \qquad\qquad 1.20 \\ \qquad - 16.11H + .790P + .751F \\ \qquad\quad 4.19 \qquad 0.45 \qquad 1.64 \\ \qquad\qquad\qquad\qquad\qquad R^2 = .766 \end{array}$$

and

$$\begin{array}{l} C_{71} = 16.183 - .295(10^{-3})R - .251(10^{-4})I \\ \qquad t = \qquad 2.12 \qquad\qquad\qquad 5.96 \\ \qquad + .968(10^{-6})S - 6.85(10^{-2})G - 3.52N \\ \qquad\quad 2.22 \qquad\qquad\quad 0.94 \qquad\qquad 1.17 \\ \qquad - 17.96H + .324P + 1.113F \\ \qquad\quad 3.78 \qquad 0.14 \qquad 4.72 \\ \qquad\qquad\qquad\qquad\qquad R^2 = .821. \end{array}$$

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[5] See [4, 6, 7, 8, and 10].

[6] For an in-depth economic analysis of this issue, see Wilson and Uhler [13] (draft available upon request).

These and other similar statistical results fail to provide an economic rationale for rate structure inversion. Rather, they lend support to the declining rate concept. Cost per kwh is a negative function of both average residential consumption (R) and average non-residential consumption (I).

In addition, the quantity coefficients remained roughly the same over the period studied. This suggests that increasing average unit costs, which most systems have experienced in recent years, are attributable to upward shifting cost functions rather than to any basic change in the slope of the static function. Properly, then, all rates should increase over time rather than being restructured so as to be positively related to quantity consumed at any given time.

In addition to the observation that consumption per customer is negatively related to average unit cost, the statistical results reported here show that average costs tend to be higher for large systems and lower for systems with relatively large amounts of hydroelectric capacity. And, especially in 1971, fuel expense was a significant determinant of cross sectional cost variations.

To summarize, intensive growth appears to have a favorable cost impact. This empirical finding is based on an analysis of quantifiable private costs. Externalities which are unaccounted for here should, of course, be identified and included in determining optimal rate levels. But, unless it can be shown that these as yet imperfectly quantified costs are an increasing function of average electricity consumption, rate structures should still conform to the general decreasing cost framework. To the extent that present rate levels do not serve to adequately internalize environmental or other social costs, a policy superior to inversion would be to enforce appropriate service and operational standards so that energy consumers would be forced to bear directly the cost of pollution abatement and other social needs.

Internalizing these costs may indeed force rates to rise, and electricity demand growth might thereby be slowed, but by an appropriate economic mechanism. The use of electric energy would be conserved just as the consumption of other products is restricted when higher costs force prices to rise. Resources would be used more efficiently in amounts and in ways that reflect a matching of all costs and benefits, while still providing consumers with an optimal level of electric service.

In conclusion, it should be noted that the prevailing system of declining block rates for electric utility service conforms to the fact of declining average unit costs as consumption per customer rises only in a very general way. There are other possible and perhaps superior forms of rate design which are quite different yet conform to the decreasing cost framework at least equally well. For example, a multiple part rate with a high initial charge for fixed costs and a constant commodity charge would be fully consistent with these findings. Which specific design within the decreasing unit cost framework is optimal is a question for further research.

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Discussion: TIMOTHY D. MOUNT, *Cornell University*

The following comments are directed exclusively to the papers on the demand for energy by Houthakker *et al.* [3] and by Wilson [5], and the emphasis is placed on the demand for electricity as this topic is common to both.

Most of the recent econometric analyses of the demand for electricity[1] conclude that the growth in consumption of electricity over the past two decades can be largely attributed to increases in population and real income per capita and to a decrease in the price of electricity relative to other commodities. The importance of this latter relationship is not, however, widely accepted by the management of electric utility companies. Another factor that has contributed to the expanded use of electricity is the substitution of electricity for other fuels, although there is no general agreement among econometricians about the magnitude of this relationship.

One additional aspect of some analyses is the specification that the quantity demanded does not adjust immediately to changes in the levels of the explanatory factors. Most analyses which include this specification find that only about 10 percent of the final response occurs in the first year. Therefore, the short-run price effect is inelastic even though the long-run effect may be elastic. Hence, one important policy conclusion is that an increase of the relative price of electricity will gradually reduce the rate of growth of electricity consumption over time, but will not be very effective for reducing consumption in the short run.

The conclusions drawn in the two papers under discussion are consistent with these introductory comments. For this reason, the remaining comments are concerned with two other aspects of these papers: namely, the usefulness of the analyses for policy formulation and an evaluation of the methodological procedures used to estimate the demand relationships.

Two questions often raised by people in government and industry about econometric analyses of the demand for electricity are the following:

(1) How important will the substitution of electricity for natural gas and fuel oil be if these substitute energy sources become substantially more expensive than electricity?

(2) If the price of electricity increases relative to the prices of other commodities, is it certain that demand behavior will be exactly the reverse of the behavior observed when this price decreased?

Neither question has been adequately considered by econometricians,[2] and inevitably the reliability of estimated demand models for developing future energy policies is still doubted. Two conclusions should be drawn. First, the predictive performance of econometric models must be appraised as new data become available to help establish the validity of the models now that the current levels of the explanatory factors are no longer consistent with their past trends. Second, it is important for econometricians to place more emphasis on interpreting their results for use in policy formulation.

Neither Houthakker *et al.* nor Wilson[3] consider the effect of alternative fuels on electricity demand. This is a serious defect not only because it places limitations on the policy implications that can be drawn from the analyses, but also because the consistency of the estimators of the remaining coefficients is in doubt due to the omission of the prices of alternative fuels. Unfortunately, data sources for these prices, particularly the price of heating oil, are scarce, and at this time, Anderson's analysis [1] of substitution effects is the most detailed.

With respect to the adjustment behavior of demand, Wilson is handicapped by the unavailability of time-series data to supplement his cross-sectional analysis. This makes it almost impossible to test the predictive performance of his estimated models as the rate of adjustment cannot be directly estimated. Although Houthakker *et al.* specify a lag structure in their models, this structure is assumed to be unaffected by changes of consumer tastes developed during a period when electricity was relatively cheap. The anticipated effectiveness of increased prices as a means of retarding the growth of consumption of electricity may be unwarranted if changes of tastes have occurred. For example, the rate of adjustment in response to price increases could very well differ from the rate when price decreases.

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[1] A summary of these studies for the years 1960 to 1972 is given in Table 1 of [4].

[2] Matters relating to the second question were discussed by Houthakker *et al.* in an earlier version of their paper.

[3] Wilson does use the average price of natural gas as the deflator for the price of electricity.

In both papers, typical marginal prices of electricity, derived from *Typical Electric Bills*, are used for estimating the price elasticity of demand. This procedure is consistent with economic theory and contrasts with the use of average prices in [4]. However, the exact specification of the price variable would be more important if there were substantial differences in the implications of models estimated using marginal rather than average prices, but no such differences were found. One disadvantage of using marginal price is that it is no longer necessarily true that a simple functional relationship exists between price and total revenue. As total revenue is an important policy variable for the management of electric utility companies, the relation between marginal prices and total revenue should be made explicit. For this reason, a procedure suggested by Halvorsen [2] for deriving marginal prices seems more convenient than using *Typical Electric Bills*. In addition, Halvorsen's procedure provides a preliminary basis for analyzing alternative rate schedules, which is one of the topics mentioned by Wilson that requires further research.

Most econometric analyses of the demand for electricity have been directed to the residential sector, but similar analyses of other sectors are required before predictions of the total consumption of electricity can be made. Such predictions are essential if, for example, one wishes to decide how much additional generating capacity should be constructed to cover future needs. In practice, models of the industrial sector are less reliable than models of the residential sector, due in part to the greater heterogeneity among industrial users. Consequently, Wilson's analysis of the demand by different industries is a valuable contribution, particularly his findings on the variation of the estimated price elasticities between industries, but data limitations once again make it impossible to estimate the rate at which industrial demand adjusts. Hence, it is difficult to assess the real importance of an increase of electricity prices for planning purposes, in spite of the generally high price elasticities reported by Wilson.

The preceding suggestions imply that additional explanatory variables should be included in the demand models. The highly multicollinear nature of available time-series data probably makes the use of regional (cross-section) data necessary to improve the efficiency of the estimated coefficients. As a result, the possible heterogeneity of demand structures between regions increases the difficulty of specifying a correct model. If a lagged dependent variable is used as a regressor, as it is in most dynamic demand models, any systematic cross-sectional variation makes the familiar ordinary least squares estimator biased and inconsistent. Specifying a dummy variable for each region eliminates this problem, but the resulting estimator may be relatively inefficient. In practice, the variance components procedures proposed by Houthakker *et al.* provide a reasonable compromise between bias and inefficiency.[4] The econometric properties of these procedures, however, are still not fully developed. For example, even though it is convenient to specify regional effects as random for estimation purposes, predictions made with the estimated models should take these regional effects into account, but they are not directly estimated. Such problems have not been discussed in the econometric literature.

In summary, both papers provide evidence supporting the contention that an increase in the price of electricity will gradually reduce the rate of growth of electricity consumption, although the substitution effects of alternative fuels are not considered. With respect to determining how large a price increase is required to achieve a specific policy objective, both analyses exhibit some limitations. The major one in the paper by Houthakker *et al.* is that the analysis is restricted to the residential sector. In Wilson's paper, the lack of information on how quickly demand adjusts makes it difficult to determine the effectiveness of pricing policies.

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[4] The sixth footnote of the paper by Houthakker *et al.* does not give a correct interpretation of the reasons presented in [4] for rejecting variance components estimation. Regional (but not state) dummy variables are used in [4] to account for cross-section differences, and instrumental variables estimation is used to account for the possibility of serially correlated residuals. Houthakker *et al.* find the dummy variable and variance component estimates almost identical, and in addition, ignore serial correlation.

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Discussion: A. Myrick Freeman III, *Bowdoin College*

The bulk of my comments will be directed at the papers by Wilson and Perry-Searl. But first I have some passing comments on the other two papers. The first comment is to call our attention to the fact that the Houthakker-Verleger theoretical and empirical models do not include any variables reflecting the availability and prices of substitutes. This omission may be significant in the case of residential electricity where natural gas is an important substitute for space and water heating and cooking.

MacDonald speaks of the trade-off between the price of oil and security and supply. There is also a trade-off between the favorable effects of economic incentives on oil supply and distributional equity. Greater use of the kinds of price and tax policies discussed by MacDonald to stimulate additional oil and natural gas supply also has the effect of increasing the wealth of holders of property rights in oil and natural gas deposits.

Consider, for example, MacDonald's discussion of natural gas price deregulation. Compare two policies, the full deregulation of natural gas prices versus the deregulation of new gas only. The latter policy is suggested as a way of avoiding the creation of windfall gains to established producers. However, there is an efficiency cost to this policy since the average price of all gas to consumers will be less than in the case of full deregulation, and total quantity demanded will be higher. The inefficiency will take the form of some combination of excessive exploration for new gas and an excessive rate of utilization of existing gas supplies.

Turning to Wilson's paper, I have three comments. First, Wilson says his results show a strong long-run price-quantity relationship, but that the short-run demand levels have been unresponsive to price variations. I find his argument unconvincing on this point. The evidence he presents is a regression of the growth in consumption of electricity per household over a five-year period on the relative price of electricity at the end of that period. In contrast to the Houthakker-Verleger paper, here the dynamics of the underlying demand model are not spelled out. It is difficult to build a plausible model in which the price at the end of a period of time explains changes in quantity demanded over the preceding period. I prefer the Houthakker-Verleger theoretical and empirical formulations of the problem.

Second, on the question of inversion of the rate schedule, Wilson makes a good point in questioning the economic rationale for inversion. We must distinguish among: (1) raising the overall level of rates because of increasing scarcity or rising cost; (2) raising rates to reflect the costs of environmental protection or to reflect increasing environmental damages; or (3) changing the structure of rates to individual users. It is only the latter kind of change which is at issue in the discussion of inverting the rate schedule; and it is untidy at best to use changes in the structure of rates as a way of trying to achieve either of the first two kinds of price changes described above.

The structure of rates to individual users should reflect the marginal cost of electricity delivered to the point of use at different use levels. For residential users, no one of which takes a significant percentage of the system load, the system cost curve is not a major factor in determining the marginal cost curve of delivered electricity. Declining system marginal costs of generation is not a sufficient justification for a declining block schedule to residential users. So, I would argue that Wilson's evidence on cost curves is not particularly relevant to the rate inversion question. The present declining of rate schedules may very well be inefficient either or both in a static and dynamic sense. The analysis of this question would go far beyond the scope of these comments. I only wish to point out that the question has not been properly posed, let alone settled, by Wilson's discussion.

My third comment on Wilson concerns the

existence of a possible identification problem in his empirical analysis of generating costs. He regresses total operating cost per kilowatt hour on a number of variables including the average annual residential consumption of electricity. If operating cost helps to determine the average price to households, and if price helps to determine average annual consumption per household, Wilson's regression might as easily be interpreted as a demand curve.

In the paper by Perry and Searl (P-S), they are grappling with the biggest and most diffuse set of issues of all of our authors. But I am afraid they are the least successful in coming to grips with these issues. P-S want to bring about a better integration of the technical and economic aspects of R & D programs. They close with a call for more extensive economic analysis of proposed R & D programs using the logic and framework of benefit-cost analysis. I support this. Of course I do not believe that the routine calculation of benefit-cost ratios for specific R & D decisions is attainable, and neither do P-S. There are major problems in the definition and measurements of benefits and costs, the role of uncertainty, and lack of information. But I would argue that it is important to bring better economic insights to bear on policy making with respect to R & D in energy. I can identify three sets of questions that P-S could have addressed themselves to, any one of which would have been a significant paper in itself, and all of which would have served to foster the greater use of economic analysis in R & D planning. What I am saying is that given the question, I would have preferred that P-S write a different paper, or actually three different papers.

The first paper would be an examination at the conceptual level of the notion of benefits. This paper would provide an economically defensible definition of the benefits of R & D in the energy area and would discuss the concepts of benefits and objectives of R & D. One of the lessons that we have learned from the way in which the practice of benefit-cost analysis developed and evolved in the water resources field is that much mischief can be done if we do not begin with a clear and hardheaded look at the concept of benefits. P-S's listing of the objectives of energy R & D is reminiscent of early federal guidelines for agencies such as the Corps of Engineers and the Bureau of Reclamation. These guidelines would provide lists of possible benefits for inclusion in a benefit-cost ratio. The lists seem to follow the rule that for benefits, count everything in sight (and if it is big, count it twice), and for costs ignore or hide as much of the cost as possible.

As a consequence, benefit-cost procedures were developed which did not have an adequate theoretical rationale. The effect was to inflate benefit-cost ratios. The result was too much investment in water resource projects and investment in the wrong mix of projects. There is a danger that the same thing could happen as we rush to expand our spending on R & D in energy. P-S could have performed a valuable service by developing the principles which could help us to draw up a sound list of benefits and objectives for R & D in energy.

The second way in which P-S could have helped us is by using their technical expertise and economic good sense to examine the list of alternative R & D areas, and to make up a list of R & D priorities based on their own intuition as to what needs were and where payoffs were most likely to be high. This paper would have spent some time discussing possible priorities among alternative conventional sources. But it would also have considered more exotic alternatives such as solar energy. But more importantly, it also would have examined the possibility for high payoffs to R & D on the demand side of the supply-demand equation. And on the demand side, there are both technical and economic questions to which R & D efforts should be devoted. On the technical side, how can R & D contribute to energy conservation and the more efficient use of existing energy supplies? On the economic side, what about R & D efforts aimed at developing an effective peak-load pricing system? What about inversion of the rate schedules? The point is that the energy problem is not a problem in energy supply, but a problem in energy supply-demand balance; there is no *a priori* reason to limit R & D spending to the supply side of the problem.

The third kind of paper would have dealt with the institutional mechanisms for guiding resources into research and development both in the private sector and in the public sector. This paper would have begun with the usual discussion of the externality, nonappropriability, and uncertainty arguments for suggesting that private R & D spending would be below the optimal level. This paper would also have suggested that the mix of R & D generated by the private sector might not be optimal, i.e., that private R & D resources might be used to ask the wrong questions.

The paper would have discussed the ways in which market structures and the distribution of private property rights might affect the allocation of resources to R & D. For example, is it reasonable to expect Consolidated Edison and Exxon to devote resources to R & D on solar energy?

Given the failure of the private market to do R & D at the optimal level and in the optimum mix, the paper would turn to the question of how the federal government should interfere to correct the private market failure. Is subsidization of private R & D the right route? And if so, how should the subsidy systems be designed? What kinds of questions should the subsidies be used to support? For example, should the government try to be a countervailing force to private market failures? Or should the government be supporting R & D on coal liquefaction and related activities, which has the effect of increasing the economic value of certain fairly closely held mineral rights?

Discussion: RICHARD L. GORDON, *The Pennsylvania State University*

The present session has given us a useful sampling of the recent flood of economic research on energy. This work is most welcome and it can be hoped, alas with not very much confidence, that policymakers learn the proper lessons from these studies. Before appraising the individual studies, it may be useful to summarize some basic views about energy problems. First, hardly anyone disagrees now that, as energy economists long warned, inept policy has badly distorted the operation of the energy markets. The record is almost bad enough to cause one to turn to Milton Friedman's contention that nonintervention is better than any policy that will actually be adopted. However, the idea that nonintervention is feasible is far more radical and unrealistic than the hope that rational argument might improve policy making. The standard welfare economist's model of public policy, applied with considerable restraint, seems a good approach for future energy policy.

In general terms, intervention in the form of either barriers or incentives to the free market should be severely limited to cases where the criterions of welfare economics for intervention are obviously met. Second, intervention should be guided to the greatest extent possible by the widespread belief among economists that price penalties and incentives are preferable to more direct intervention. To be more concrete about this, there are numerous areas of energy policy involving efforts to control possible monopolies, correct possible undesirable income distribution effects, correct tax inequities, and overcome supposedly intolerable production fluctuations. These arguments were used to rationalize such actions as natural gas regulation, federal mineral leasing policy, state regulation of oil production, and mineral tax policy.

In every case the argument was dubious; the efficacy in attaining the stated goal of the policy was questionable; the overall effects ranged from negligible to appalling. The time has come to abandon the search for tenuous rationales for intervention.

As for alternative policies, the cases of oil import control and environmental regulation are prime examples of the defects of current policy instruments. This is clearest with environmental policies. It seems quite apparent that the textbook case for use of environmental damage charges rather than direct controls has been triumphantly vindicated by recent experience. The key points in the argument are that regulators were likely to be incompetent in evaluating the optimal method of compliance and that the pressure of charges was a powerful incentive to private action.

The most graphic example has been the effort to impose rapidly stringent standards for sulfur oxide emission control. Such standards could not have been implemented without causing intolerable upheavals in the energy markets without the availability of a workable scrubber to remove sulfur from the stack gas of plants burning high sulfur coal. The U. S. government has long argued and indeed continues to argue that such technology would be developed soon. However, both its own most recent appraisals if read critically and writings by those involved in attempting to make scrubbers operational suggest that technical success remains elusive and that costs will be far higher than the government predicted. Apparently a second fiasco is emerging in auto emission control.

The experience may not have proved taxes are a good incentive but have indicated that dictation of technology works badly. It encouraged putting much of the onus for developing technology on the regulators while the pollutor, perhaps unconsciously, waits for a failure of the development effort to force a retreat on standards. The oil import problem is a less dramatic example. Overcomplexity was a serious fault, but this was secondary to the complete failure until 1970 to develop a sensible rationale for the policy. The real problems of security of supply were ignored in the process of using security as an excuse for protectionism.

This leads naturally to a second basic argument. Public policy must be guided by rational economic analyses, and these analyses must be grounded in the best possible statistical bases. Economic analyses of energy problems has been most fruitful but is suffered from three defects. First, there has not been enough of it. Second, it has been conducted using a grossly inadequate data base. It has been observed in many contexts that the data gathering services in the world have lagged badly behind the improvement in mathematical analytic techniques and in computer technology. This principle applies at least as much to energy problems as to other areas. Finally, no matter how good the studies, they still must overcome the difficult-to-alter prejudices of policymakers.

Turning to the individual papers, I will begin with Stephen McDonald's view of incentives to energy supply. Professor McDonald deserves commendation for his willingness to undergo double, double jeopardy. This is the second time this year he has been given the thankless task of using the concept of incentives as a basis for evaluating energy policy. In both cases, he had to face my arguments that the incentive concept is not a particularly useful framework. Both times he has deftly transcended the problem by quickly passing over the conceptual questions and concentrating on specific interesting issues.

There is little that can be added to his useful synthesis on oil and gas market elasticities. His presentation clearly shows that econometric analysis of energy supply has produced a formidable challenge to the conventional view that self-sufficiency in energy requires a massive development of synthetic fuels. These estimates, to be sure, are quite primitive and hardly the basis for ignoring new energy technologies. However, they do suggest that the available evidence for the need for massive research and development programs is less than convincing.

One modest aside is that one aspect of the new oil import program that needs fuller treatment is the move toward tariffs on refined product triple those on crude oil. The key question is the adequacy of these incentives in encouraging domestic refining. This would require cost engineering studies of the type outside observers are ill-equipped to undertake and for which no mechanism exists to secure the necessary data from the companies.

Turning to his discussion of tax policy, Professor McDonald has continued his ingenious efforts to bring sanity into discussions of minerals taxation. It is helpful to place these issues in a context that permits rational argument. It might be added that the effect of the approach is to undermine the case for special minerals taxation more effectively than several generations of tirades. The strong conditions that must be satisfied to justify intervention—that special distortions must exist and create damage sufficient to offset the costs of a special tax provision—appear unlikely to be satisfied in practice. What holds for Professor McDonald's earlier arguments on depletion allowances seems to hold also for his rationale of exploration incentives. The oil industry by use of joint ventures in exploration and other devices has already developed methods for sharing information widely. It is not clear that the imperfections of this approach are so great that they justify the expense of further complications of our already intolerably complex tax laws. It may be noted, moreover, that it is particularly ironic that these joint ventures that contribute to more efficient exploration are being widely cited as evidence of collusion.

Searl and Perry have effectively shown the drawbacks of the present fascination with R&D as an energy problem panacea. My main complaint is that they may not have gone far enough. They correctly suggest that expansion of conventional energy supplies is the primary immediate need. I would go a step further and argue that the prospects are considerable that such expansion might obviate a great deal of R&D.

This would be trivially true if Adelman's arguments about world oil were more widely accepted by oil consuming countries. The replacement of the present pusillanimous posture towards OPEC by an effort to resist oil price increases would be most welcome. This seems a remote possibility, not because Adelman's ideas are defective, but because consuming countries lack the courage even to discuss them seriously, let alone apply them. Thus, the United States may indeed be better off protecting its fuel industries against imports.

It may be that the response of conventional energy resources to such policy might be substantial enough to preclude for many years the use of new energy sources. If this occurs, it would be better to work on very long-run projects such as fusion or solar energy. To be sure, the unleashing of conventional sources will take several years and if my optimism is excessive, valuable time would have been lost if R&D work had not been started. Nevertheless, at the very least the R&D effort ideally should involve a mechanism to insure that appropriate responses be made to developments in the supply of conventional resources. Moreover, the argument about pruning support as information accumulates can be generalized somewhat further than it was by Searl and Perry. It appears that many options can be ruled out fairly early in the game if they are subjected to rigorous economic analysis. Thus, the relevant rule is that at all stages impartial review to establish whether an alternative has a reasonable prospect of viability should be undertaken. In short, I endorse the Searl-Perry proposals for review and suggest it start as early in the game as possible.

As an aside, I might point out that the SST and the breeder are better seen as defective on conventional economic grounds than as environmental menaces. The menaces may exist, but the critical point is that it really was never worth finding out whether serious environmental problems existed because even if they did not, the SST and the breeder were dubious propositions.

This leads me naturally to consideration of Searl and Perry's list of typical claims of benefits of R & D. The list has a suspicious resemblance to an effort to reformulate the absurd AEC justifications for the breeder into a more respectable form. I would like to suggest an alternative and perhaps more useful view of these amended justifications for energy R & D.

These rules represent an effort by those Searl and Perry are trying to portray to provide a vulgarized version of the meaning of the economic concept of socially optimal allocation of resources. However, by departing from the explicit economic concept, the criteria have produced serious confusion. Only when we recall that each of the contributions is a commodity with a cost as well as a benefit can we reach sensible decisions. The public discussions of energy problems are replete with nonsense arguments about security of supply, the balance of payments, supply increase and conservation. In every case, the error lies precisely in neglect of the principle of optimal resource allocation. Along these lines, let me quibble about the concept of noneconomic justifications for R & D. As a purist, I would insist that if the case for R & D cannot be justified within the framework of economic analyses, it does not exist. There may be nonmarket justifications but never noneconomic ones.

To a noneconometrician, the most interesting result in John Wilson's paper was its negative conclusion about the inverted rate structure. This concept has such a poor theoretical basis that it is not surprising that its use does not produce desirable results. Inverted prices have always seemed a particularly harebrained way to solve the peak-load pricing problem. It seems doubtful that an adequately strong correlation prevailed between total consumption and peak usage to justify rate inversion.

I will limit my observations on the Houthakker-Verleger-Sheehan paper to their policy conclusions. Their observation that price rises will reduce energy consumption only refutes the most naive defenses of rationing. Their elasticities unfortunately are low enough to be seized as supporting evidence by those who believe that intolerable price rises would result if we relied on the price system. Thus the present estimates must be supplemented by discussion of the defects of the assertions about the undesirability of significantly higher prices before a satisfactory anti-rationing argument is complete.

Discussion: WALTER J. MEAD, *University of California, Santa Barbara*

My assignment from the chairman is to comment on the Houthakker, Verleger, and Sheehan (HVS) paper. Two quite different papers have been presented by the authors. All discussants were sent copies of a paper by Houthakker and Verleger (HV) prepared for the Ford Foundation Energy Policy Project. Then 24 hours prior to this session, copies of the HVS paper were distributed to the discussants. The two papers differ in data base, methodology, and conclusions. The HV conclusions indicate that for the United States as a whole, the short-run elasticity of demand for gasoline is —.43 and the long-run elasticity is —.75. Income elasticity is shown to be +.44 and +.77 in the short-run and long-run respectively. The analysis is based on real, per capita consumption for each of 48 states, plus the District of Columbia, pooled into 9 regions, and pooled again for the entire U. S. For these nine regions and the nation, 21 out of 30 coefficients are significant at the 95 percent confidence level. All price elasticities are negative and income elasticities are positive as expected. This analysis is based on annual data for the periods 1949 through 1971.

The HVS analysis is based on quarterly data from 1963 through 1972. Sharply differing conclusions are reached. The short-run elasticity of demand is found to be —.075 and long-run elasticity is —.24. Income elasticities are +.30 and +.98 in the short-run and long-run respectively. The HVS model was tested by simulating gasoline consumption for the first two quarters of 1973. The results showed that the model over-predicted consumption by 3.3 percent for the first quarter and 7.6 percent for the second quarter. One of several possible explanations for the discrepancy is the HVS model underestimated absolute values of demand elasticities in the short-run. The simulation suggests that the higher price elasticities shown in HV study may more accurately reflect the true demand elasticities.

I have elected to devote my limited time to exploring policy implications following from the analysis. It was my pleasure to work with the authors in developing their models for the Energy Policy Project. Any objections I had to their methodology were made known to them during the course of their study.

Familiarity with the Washington, D. C. policy-making circuit leads one unmistakably to the conclusion that noneconomist policy makers habitually assume that demand elasticities are zero. This appears to be particularly true in the energy area. For example, prorationing procedures make a point of ignoring price and simply ask about the quantity of crude oil demanded each month. Similarly, under the import quota system crude oil imports into PAD V were calculated by subtracting estimates of quantity supplied from quantity demanded in the region. In this case, both supply and demand functions were presumed to have elasticities of zero. Even though the authors of the HVS study find demand elasticities to be relatively low, they conclude that "the arguments made for energy rationing by many politicians and some economists are unfounded. The market mechanism by itself appears to be capable of bringing about the necessary adjustments in demand."

While the HVS author's simulation of 1973 gasoline demands suggest the possibility that their demand elasticity coefficients may be too small in an absolute sense, a case can be made that even the higher HV demand elasticities may be too small. The base period for the HV analysis was 1949 through 1971, per capita, real prices, by state. In this base period the real price of gasoline declined through 1971. It appears probable that at least in the next four years the real price of gasoline will increase and by large amounts. In the 1949–71 base period there is no record of three major market forces that must be accommodated in the present and near future. First, we now have wide publicity given to a concept called the "energy crisis" and to gasoline shortages. Second, in the base period there is no record of an actual shortage of gasoline at prevailing prices. Third, there is no record in the base period of anticipated large price increases. The presence currently of all of these market forces will probably lead consumers to react quickly to price changes relative to past experience. Therefore, we may experience more than a 4.3 percent reduction in quantity demanded resulting from a 10 percent price increase in the short-run. This result, however, is likely to reflect both movements up the demand curve and shifts in the demand curve.

Recent statistical evidence tends to support this expectation. Automobile purchasers clearly are anticipating significantly higher gasoline prices. November 1973 U. S. automobile sales were down 13.0 percent relative to November 1972. The last week of November 1973 showed a 20.07 percent decline over the preceding week. A breakdown of automobile sales by product line indicates a shift from large, low-mileage cars to smaller cars. Only American Motors, concentrating on smaller cars, recorded a sales increase. Sales by AMC increased 18.6 percent from November 1972 to November 1973. Further, foreign cars which as a group deliver higher gas mileage, increased their market share from 13.5 percent in November 1972 to 14.6 percent in November 1973. Furthermore, recent data on crude oil and petroleum product stocks indicate surprising reductions in quantities demanded. Crude oil supplies available in the United States from both domestic production and imports declined from their peak (week ending October 19, 1973) by 9.6 percent (week ending Dec. 14, 1973) (IP. 4). However, crude oil stocks in the United States increased 1.2 percent over the same time period. This record strongly indicates a substantial reduction in crude oil usage over a two month period. We have no analysis of the respective roles of regulation, fair weather, and price in producing this result. However, the result is consistent with the hypothesis that anticipation of higher prices and shortages, as well as actual price increases, have produced a larger reduction in consumption than even the HV short-run elasticities would indicate.

Washington policy makers are currently debating alternative policies for dealing with the gasoline shortage. Prominent choices include the following: (1) permit the price system to ration gasoline, (2) impose a coupon rationing system for gasoline, (3) impose an excise tax on gasoline to reduce consumption, and (4) impose an excess profits tax on oil companies to reduce windfall profits resulting from higher product prices.

The HV analysis, and to a lesser degree, the HVS analysis, lends support to the market price approach. This would be especially true if the short-run elasticity is even greater than —.43 (absolute values) as shown in the HV analysis.

Given the failure of the HVS model to predict accurately first half 1973 gasoline consumption, we may use the HV demand elasticity (—.43 in the short-run) to predict a market clearing price for gasoline. Assuming that the short-run elasticity of gasoline *supply* is zero, that there will be no growth in real income for the duration of the energy crisis, and that the estimated shortage at fixed prices prevailing one year ago amounts to 20 percent of demand, then the market clearing price would become 53.5 cents per gallon. However, the demand elasticity estimates were made in terms of real prices. Hence, we must add an inflation factor. Assuming an 8 percent inflation rate, the market clearing price becomes 59 cents per gallon. This is a 47 percent increase over prices prevailing on December 19, 1972 for major brand, regular gasoline, including excise taxes.

Two objections to permitting the price system to perform its allocation function are commonly raised. First, significantly higher prices would impact heavily on low income people. Second, windfall profits would accrue to oil producers.

The first objection should be resolved by separating the problem into two issues: the resource allocation issue and the income distribution issue. The impact on low income people can be estimated. Very low income people do not own cars and hence the direct impact of higher gasoline prices on them would be insignificant. However, for a low income group driving 5,000 miles per year and achieving 15 miles per gallon of gasoline, a 47 percent increase would lead to a direct budgetary impact of $57 per year. This calculation makes the absurd assumption that the elasticity of demand for gasoline by this income group has a value of zero. In addition to the direct impact, there is an indirect impact on consumers due to price increases resulting from higher gasoline costs paid by others. If the indirect cost is of a magnitude equal to that of the direct cost, then the total cost to low income recipients would be $114 per year. The income distribution issue can be resolved by inincreasing the income supplement to low income people by approximately $114 per year. This income class would then be better off than before. They would be free to spend their additional income supplement in any way which maximizes their satisfaction from consumption. With the income distribution matter resolved, the price system may then be allowed to allocate gasoline in an efficient manner.

The windfall objection may be resolved by imposing excess profits taxes on oil producers as an alternative to price control. However, an excess profits tax is extremely difficult to administer. An arbitrary base period is required which inevitably favors some firms while penalizing others. As proposed by the Administration, the excess profits tax can be avoided by allocating increased profits to oil exploration and development. This loophole might lead to misallocating too much of the nation's resources to this particular use. Finally, as proposed, the excess profits tax would be phased out over a five year period when the price of oil increases to about $7 per barrel. It is a temporary expedient.

Given these difficulties of the excess profits tax in principle and practice, there is an attractive alternative available to the nation. We may take this opportunity to rid our tax system of oil tax subsidies not justified by net external benefits. Specifically, we may eliminate or reduce the depletion allowance, the intangible drilling cost expensing provisions, and the foreign tax credit. Thus, instead of adding a new tax which is difficult to administer and probably would have a short life, we might take the opportunity afforded by very high oil prices and consequently attractive profits to reduce or eliminate existing tax subsidies. Rough calculation suggests that as a result of moving to a free price system (eliminating price control on both oil and natural gas), the increase in profit would be at least twice the magnitude of the loss of existing tax favors. Thus, a free price system, freed of oil tax subsidies, would still produce a substantial increase in incentives for oil and gas exploration and development. The HV and HVS analyses provide solid bases for analyzing the probable demand behavior following from public policy alternatives regarding energy prices. We are indebted to the authors for the advances provided in their papers.

Communications

THE AAEA: ITS RESPONSIBILITY FOR INSTRUCTIONAL LEADERSHIP*

In the 54 years since its founding in 1919, the American Agricultural Economics Association has been an association primarily of researchers, not teachers. Occasionally an individual, a small group of individuals, or the association leadership has shown an interest in the teaching function of its many members. The Association at the 1972 Gainesville meetings, for example, adopted a resolution establishing

> . . . a special committee . . . to evaluate the student affairs activities of the Association; that this committee be concerned not only with existing student affairs activities but also with potential programs and with the role of undergraduate professional education.

President Castle in appointing the special committee provided these objectives:

1. To explore the meaning of and need for undergraduate professional education in agricultural economics.
2. To explore the relationship between the Association and student activities.
3. To explore how the Association manages its educational activities.

The purpose of this paper as assigned by the special committee chairman James Plaxico was ". . . to prepare in written form a statement briefly outlining the background and development of the student activities as they now exist and as they might be."

The AAEA and Undergraduate Education, 1919 to 1973[1]

The most definitive history of agricultural economics is the 1,121-page volume, *The Story of Agricultural Economics in the United States, 1840–1932,* Taylor and Taylor [2], who allocated 28 pages to undergraduate teaching. In 54 volumes, 1919 through 1972, the Association's *Journal* [1] has published 95 articles, notes, and proceedings reports on teaching. Of those, 65 deal primarily with undergraduate instruction: 12 major articles (one every 4-1/2 years), 18 notes, and 35 reports. The proceedings of each of the three teaching workshops—at Bemidji (1963), Blacksburg (1969), and Gainesville (1972)—sponsored by the Association have been reported in *Journal* supplements.

No careful analysis is needed to establish that teachers have made only limited use of the *Journal* as a forum for the exchange of instructional information and ideas. Perhaps most importantly it indicates teachers do not report on instructional programs either because they believe the *Journal* does not want their articles or because they have little interest in reporting their experiences.

In 1919 the Association established a committee on teaching; committee reports appeared in the 1920, 1921, 1922, and 1923 *Journal* issues. At the 1925 annual meeting a roundtable discussion was held on the topic, "Should there be two four-year curricula in agricultural colleges, one based primarily upon the natural sciences and the other upon economics, accounting, statistics?" At the 1932 meetings, three papers on teaching marketing were discussed; in 1933 members discussed undergraduate instructional problems; and after 1940 the executive board rather regularly dealt with instructional questions. For example, in 1941 it commended the American Council on Education, the General Education Board, and the Social Science Research Council for its "Exploratory Study on Recruiting and Training Personnel in the Rural Social Sciences."

The Association's approval in 1948 of E. L. Butz's recommendation that it establish student chapters apparently ushered in the present era of undergraduate student participation in the Association. During the 1950's leadership in establishing student chapters and a student program at the annual meetings came from Association members Joseph Ackerman, B. W. Allin, A. G. Ball, E. L. Butz, R. J. Mutti, R. G. F. Spitze, F. H. Wiegmann, and E. C. Young. During the 1960's leaders for improving student contests and for initiating teaching awards and teaching workshops included J. B. Sjo, C. V. Hess, and K. B. Boggs, who received strong encouragement from executive committee leaders J. Ackerman, S. O. Berg, and L. S. Hardin. Today student activities at the annual meetings include a debate contest, begun in 1953, and a speech contest, begun

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* Contribution No. 538, Department of Agricultural Economics, Kansas Agricultural Experiment Station, Kansas State University. I am indebted to my Kansas State colleagues A. W. Biere, P. L. Kelley, C. V. Hess, Frank Orazem, and M. L. Manuel for discussion of the material presented in the paper and to the members of the special committee for their suggestions: E. M. Babb, D. J. Epp, J. G. Kendrick, L. V. Manderscheid, J. S. Plaxico, and W. J. Wills.

[1] The activities of the association and its predecessors were limited to the years the *Journal* has been published.

in 1956; since 1964 the Association has sponsored an essay contest annually. Though no records are available to document student participation, it is safe to say that only a small portion of all students majoring in agricultural economics have participated in the contests or attended the annual meetings. Of those who have participated, few have returned to annual meetings of the Association except those who later completed their Ph.D.'s. Undergraduate membership in 1973 was almost nil.

At the Association's August 1964 Executive Committee meeting, an annual award was established for the distinguished undergraduate agricultural economics teacher. Since 1965 the Association has given nine such awards; in 1971, 1972, and 1973 two were given, one each to a teacher of more than 10 years experience and to a teacher of less than 10 years experience.

The Association has sponsored three undergraduate teaching workshops: two (1963 and 1966) organized by the Student Affairs Committee, one (1972) by the Education Committee. For the first workshop (1963) held at Bemidji State College, Bemidji, Minnesota, on improving undergraduate instruction in agricultural economics, the Association provided $5,000. For the second (1966), "An Inquiry into the Nature of Agricultural Economics with Implications for Improved Instruction," held in cooperation with CEANAR and the National Academy of Sciences at Blacksburg, Virginia, the Association provided $2,000. For the third (1972), "Improvement of Education in Agricultural Economics by Defining Goals, Developing Curricula, and Improving Instruction," held at Gainesville, Florida, the Association again provided support.

The Association's undergraduate instruction activities were handled by the Student Affairs Committee until 1970, when an Ad Hoc Committee on Education in Agricultural Economics was formed; a year later that committee was made a standing committee. Until 1973 the Association had two committees that dealt with undergraduate instruction. The Executive Committee has now combined the two committees. The distinguished-teacher award program is handled by a subcommittee of the Awards Committee.

In 1969 the Association, to formalize its responsibility for the Student Section, adopted Article XIII of the Bylaws, which specifies the relationship between the AAEA and the SS AAEA. A constitution for the Student Section also was approved in 1969.

The 1973 budget allocation in support of the Student Section had a modest beginning in 1952, when Ackerman recommended awarding the winning debate-team members a 5-year subscription to the *Journal*. Later $75 cash was made available for suitable awards. In 1956 the Association budgeted $75 to cover the cost of a student newsletter. In 1962 the first funds were budgeted to support operation of the student contests. In 1972 the Association provided $1,140 to support student activities.

Problems in Undergraduate Agricultural Economics Education Activities of the Association

A survey of the minutes of the Association, officers' reports, and committee reports reveals that the Association throughout its history has never been wholly satisfied with its undergraduate program. In the early years, 1919 to 1949, the Association apparently limited itself to publishing articles on instruction and to having discussion groups at some annual meetings. About 1949 the Association began to examine the role it should play in undergraduate work.

F. F. Hill, in his presidential report in 1951, stated, ". . . we have not arrived at a satisfactory solution to the basic long term problem of how to organize this activity [on student affairs] so that it will function smoothly and effectively on a national basis, year after year."

In 1953 President T. K. Cowden appointed a committee to review relationships with and make recommendations on the student activities (Ackerman, Mutti, Butz).

The August 1956 minutes of the executive committee reported: "The need for further analysis in the entire student situation was pointed up."

To provide continuity of the student activities, in 1957 a Student Activities Committee Chairman was appointed for a three-year term. Gordon Ball, chairman of the committee, in 1958 reported, "Attendance is still poor at all student events and one of our major problems yet to be overcome."

In 1961 the Executive Committee requested the Student Activities Committee to review career opportunities in agricultural economics. So in 1962 the committee made a comprehensive survey of all university departments of agricultural economics to determine what activities should be given priority. As a result the 1964 and 1967 workshops and the distinguished teacher award were initiated.

In studying the professional needs of the Association, in 1969 the Professional Activities Committee recommended that the Association establish an education committee to promote instructional activities within the Association. That was established.

Examples noted here show that there has been a continuing concern within the Association with its instructional programs. The 1973 special committee is the latest of a series of individuals and groups assigned responsibilities for defining and finding a satisfactory way to fulfill Association instructional responsibility. The most pressing undergraduate instructional problems the Association must deal with are:

1. *The attitude of the Association and its members toward undergraduate instruction.* Undergraduate instruction has been treated by the Association

as a special activity of agricultural economists, even though for most members on university faculties it is a very important and continuing part of their professional life. The Association periodically has sponsored special programs, treated as special activities and not as integral parts of the professional activities. In choosing its leadership the Association never has selected as its president a member who is primarily an undergraduate teacher. Not one Fellow of the Association has been primarily an undergraduate teacher. The highest recognition the Association bestows upon its teachers is to select them as members of one of the teaching committees or their chairmanships and to give them the distinguished teacher award.

Undergraduate instruction has not been viewed among agricultural economists as their most prestigious activity. To be primarily an undergraduate teacher, it is generally believed one must be willing to forego establishing a national professional reputation. It is widely believed recognition will be limited to one's own university and among one's own students. The undergraduate teacher does not have disciples among professional agricultural economists as does the graduate teacher, whose students become his advocates among their peers. The undergraduate teacher does not have a national forum and readership that the outstanding researcher has in his publications. Often on our own campuses undergraduate teaching is not an important promotion criteria. Hence, we find the attitude that there is little professional payoff in undergraduate teaching.

2. *The Association's responsibility to undergraduate instruction.* By sponsoring the Student Section, the contests and teaching awards, the Association has not centered its attention on the core problems and interests existing in undergraduate education.

By showing an interest in students, the Association has tried to fulfill its responsibility to the teaching activity, but efforts have been disappointing. The quality of instructional programs has been affected little through the student participants. The teachers are the vital link through which the Association can be effective, but to be effective the Association must do more than sponsor special programs such as the three workshops.

The Association has not fully dealt with the most important ongoing issues such as:

(a) Defining the employment market for which we are educating students.

(b) Defining quality-instruction and achievement levels of graduates.

(c) Defining the scope of agricultural economics instruction and the content of courses.

3. *An organizational structure to deal with undergraduate-instructional responsibility.* The Association has not provided an organizational structure to give strong support to undergraduate instruction. Its *Journal* in practice, if not in intent, has evolved primarily for the exchange of information among research economists. Its annual meeting's program is primarily for the exchange of information among research economists. Its two committees that treat instruction responsibility as a special activity have not been effective in establishing instruction as an important function.

Alternative Commitments to and Activities in Undergraduate Education for the Association

After 54 years it is time for the Association to make a clear, strong decision on its responsibility and commitment to undergraduate education. Three strategies seemingly can be considered:

1. Abandon all commitment and responsibility to undergraduate instruction.

2. Continue the current low-key, disorganized, and somewhat ineffective policy of leaving the commitment and responsibility to the initiative of individuals or small groups.

3. Accept a strong commitment to and responsibility for undergraduate instruction through a strong, effective action program.

The stated objectives of the Association are [1]:

> To promote and maintain high standards of accomplishment in research, teaching, and extension in agricultural economics by fostering study, writing and contacts which contribute to this end.
>
> To promote interest in and understanding of the profession of agricultural economics among college students.
>
> To solicit the interest and support of farmers, consumers, and other economic groups in the study and analysis of the economic problems of agriculture.

If we accept those objectives, strategy #1, abandonment, can be rejected as inconsistent with the Association's objectives. Strategy #2, continuing present policies and programs, is consistent with, but ineffective in fully achieving, Association objectives. Therefore, it is in the interest of the Association to review carefully its objectives and its programs for undergraduate instruction to decide how the Association can best achieve an effective undergraduate program.

If, as I assume it will, the Association reaffirms its objectives for undergraduate education and directs efforts toward strategy #3—accepting a strong commitment to and responsibility for undergraduate instruction through a strong, effective action program —a major effort must be made to explore and choose among alternative means. I set forth these possible alternatives for the Association to consider:

1. The Association has had difficulty in identifying its role in undergraduate instruction partly because it has failed to define clearly the nature of its undergraduate instructional mission.

Preparation for careers has a wide range of professionalism—from medicine to engineering to agriculture to business administration to liberal arts. Undergraduate agricultural economics is not highly career specific, nor is it a general liberal arts experience; it is, rather, a combination of professional (agriculture and economics) and liberal education.

Many graduates who do not receive the Ph.D. degree become bankers, brokers, farmers, and salesmen who do not identify their career and professional interests with the Association. The real strength in undergraduate instruction in agricultural economics has been in preparing graduates for those careers by combining technical, agricultural, economic, business, and general education. If we accept that, it is unreasonable to expect agricultural economics majors to identify closely with the Association unless or until they are Ph.D. candidates. Assuming that is true, any student-centered program of the Association most likely will be only modestly successful in gaining student participation. The undergraduate student just does not see the Association contributing to his occupational welfare. If, however, the undergraduate instruction were highly professionalized, then the Association could identify with the professional aspirations of undergraduates and develop a more effective undergraduate program.

It does not seem desirable to attempt to change either the nature of the Association or the nature of the undergraduate program. Therefore, let the Association continue to:

(a) Sponsor the Student Section, even though it will not generate wide student participation.
(b) Support student contests and awards.
(c) Support a Student Section program that emphasizes employment opportunities, standards for professional development, and representation from employers.

2. The real benefits of a Student Section program will be determined by the support of teaching faculty in the various departments. I believe the recommendations following will provide for stronger teacher support.

The Association, to be effective in improving undergraduate instruction, must consider a faculty-centered program as an alternative to a student-centered program. It can:

(a) Develop and establish Association priorities so that those involved in undergraduate instruction recognize the Association as contributing toward their professional welfare.
(b) Provide at the annual meetings a strong instructional program—rather than treating teaching as a special activity.
(c) Offer (if the awards program is continued) a distinguished teacher award, as well as awards for preparing instructional materials and programs.
(d) Encourage and solicit teachers to report on their experiences and problems for publication in the *Journal.*

3. The Association should provide leadership in course and curriculum development and establish performance guidelines:

(a) Define the scope of subject matter to be included in undergraduate agricultural economics.
(b) Establish criteria for subdividing subject matter into courses.
(c) Establish criteria for curriculum development.

4. The Association should have an interest in textbook and teaching-material needs and encourage development of both.

5. The Association should consider criteria for teaching methods in graduate education.

6. The Association should organize itself to provide coordinated leadership within the Association, among universities, and among individual Association members. I recommend it establish one strong committee authorized to establish the necessary sub-committees.

Summary

The American Association of Agricultural Economics should more clearly define its undergraduate education mission. The issue is so important it should be given top priority.

Historically the role of the Association in undergraduate instruction has been one of neglect. Periodically special programs on teaching have been organized and support has been given to the Student Section. Through publishing research findings, the *Journal* and Association have given strong but indirect support to teaching by providing additions to economic knowledge.

Originally the Association's role was based on the research-teaching-extension philosophy of the land-grant concept. As research became more basic and complex, the complementarity between research and undergraduate instruction all but disappeared, and the Association's emphasis on research soon had less relationship with the undergraduate responsibilities of many of its individual members. Work in professional agricultural economics soon was limited to those holding doctorate degrees and trained primarily to be economic researchers. Simultaneously the undergraduate program moved to a more general type of education. The drift, which became apparent in the late 1940's and 1950's, generated concern about the Association's responsibility to undergraduate instruction. Between 1948 and 1972 the Association attempted to reconcile that separation but was only partially successful. The attempt, a useful and probably necessary exploratory experience, prepared the Association for a major effort to establish an effective policy toward undergraduate education.

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THE FOOD STAMP PROGRAM AND UNIT-CONSUMER HOUSEHOLDS—A SUGGESTED REVISION*

Recent articles in this *Journal* concerning the operation of the Food Stamp Program (FSP) call attention to the need for research in this important policy area [2, 4, 5]. Hiemstra seems quite right in calling for rigorous ". . . analytical efforts, not rhetoric, which abounds" [5, p. 109]. To date the FSP has not been subjected to rigorous performance analysis. As a result certain questions regarding program efficiency and the degree of horizontal equity[1] current operational procedures afford remain unanswered.

As the FSP grows both in number of participants and amount of dollars distributed, these questions become more important. The average number of monthly participants has grown from about two million in 1968 to almost 12 million in 1972. Dollar distribution has increased from about $174 million to almost $2 billion in the same time period. There appears to be little question that the FSP will, in the near future, continue to be relied upon heavily for food distribution to low income families.

Although the present paper does not fully satisfy Hiemstra's plea for rigorous analytics, its purpose is to call attention to previously published research and to suggest certain revisions in the federal regulations governing distribution of food coupons. Specifically, it is proposed that the authorized allotment of food coupons be based explicitly on both the number of persons and the age-sex composition of the receiving household unit. It is argued that such a revision would make the FSP more efficient[2] as well as more horizontally equitable. Scale coefficients estimated by Price [8] are used to illustrate how a specific unit-consumer scale might possibly be utilized in altering the presently existing allocation process.

Since there is apparently some disagreement among the various authors as to what the objective of the FSP has been, is now, or ought to be, some statement about the program objective assumed in this paper seems in order. Ordinarily it is the task of the analyst, given some stated objective, to determine whether or not current or planned procedures are capable of generating the hoped for results in the most efficient and equitable manner. In scrutinizing current FSP procedures it seems difficult to argue convincingly that the FSP as it currently operates is designed to improve the nutritive value of the diet of poor families, although some of this does probably occur. Presently it is the purchasing behavior of the household unit using food coupons and not the FSP which determines the nutritive value of the diet. Since there is little question about the ability of the current FSP to increase food purchasing power of participants, that is the objective assumed throughout this paper.

Unit-Consumer Scales and Household Food Expenditures

The effect of household composition on the pattern of expenditures may well be important data for public policy formulations, especially in food or income distribution programs. The household represents not only the unit of observation but ordinarily is also the unit receiving the funds. Since family units differ in physical make-up as well as in their ability to generate income, the specific requirements certain household members place on the family budget for particular items must be established if federal distribution programs are to achieve some degree of horizontal equity.

Prais, Houthakker, Brown, Price, and others have developed procedures whereby such individual requirements might be estimated [3, 6, 7, 8]. Generally the methods entail estimating scale coefficients for each of the individual age-sex types in the household and expressing them as a proportion of some "standard" type (i.e., an adult male). The fundamental Engle relationship which expresses expenditures as a function of income is reformulated to reflect the household expenditures for a specific item (i.e., food) on a per person basis adjusted for age and sex differences. Two methods of estimation have typically been utilized.[3] The first, suggested by Prais and Houthakker [7], is an iterative process whereby alternative values for the income elasticity for food are chosen by the analyst. The set of parameter estimates and the income elasticity for food which maximize the multiple correlation coefficient (R^2) are then chosen, and the scale is formed. The second method, developed by Brown [3], obtains an estimate of the income elasticity for food directly from the data. Regression coefficients are obtained by ordinary least squares and the scale is formed. The estimated coefficients in either case are unbiased but inefficient estimates of the true parameters. Brown [3] and Price [9] both provide techniques whereby more efficient estimates of the parameters can be obtained. In addition, Price has developed models which allow for estimation with variable income elasticities [8].

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[1] Horizontal equity is a widely accepted principle of taxation. The concept refers to the equal treatment (requirement to pay or legal right to receive) of equals.

[2] Given a specific level of total public expenditures for the FSP, an efficiency criterion would require that for those expenditures the "food purchasing power of the poor" be at its maximum. To the extent that the suggested revision would provide increased food purchasing power on the basis of a more objective measure of need than is the case presently, efficiency is increased.

[3] The interested reader is encouraged to see Price [10] for a complete development of the estimation procedures.

Table 1 presents the results of three previously published studies. In each case, estimates of equivalence scales are based on samples of national populations (U. S. and British). As Table 1 indicates, regardless of the method of estimation or the sample size, the scales appear to be quite stable.[4] This stability is rather important if such scales are to be used in public food distribution programs. Administrators must be in a position to defend their choice of scale coefficients (just as they must now defend the current distribution scheme based upon the number of household members and income). Claims of discrimination or otherwise unfair treatment could only be refuted if the magnitude of the scale coefficients is somewhat invariant to the method of estimation.

Table 1. Unit-consumer scales for food with comparisons

Age-Sex Type	Author		
	Prais	Brown	Price
Adult Couple	1.86	2.0	2.0
Male (15–19)	.82	.83	.77
Female (15–19)	.65	.85	.69
Adolescent (9–15)	.69	.92	.57
Child (5–9)	.55	.71	.59
Child (3–5)	.51	.71	.46
Infant (0–3)	.32	.54	.46
Income elasticity	.53	.31	Unknown
R^2	.983	.985	Unknown
Sample size	2,200	5,924	2,300

Sources: [3, 7, 9].

Unit-Consumer Scales and the FSP

Results obtained in previous studies indicate that differences do exist in the number of unit-consumers within households of the same size. Further, they indicate that regardless of estimation technique, the unit equivalent scales are rather stable. Yet, food stamps are currently being distributed without the benefit of such research. Operationally, it is currently being assumed that food expenditure requirements per family vary only by the number of household members, *ceteris paribus*. Even though the current price chart presumably reflects economies of household size, a food distribution program which is based explicitly on the number of unit-consumers in the household, rather than the number of household members, is intuitively more appealing. Such a program would seem more efficient and more equitable than is the case presently.

Consider two families, each with five members and earning $150 net income monthly. Each family currently receives approximately $86 in food coupons monthly. If the present coupon distribution scheme were based on Price's estimated equivalence scales, a family with two adults, two teenage boys, and one teenage girl (4.23 equivalent adults) would receive about $70 in coupons while a second household with two adults, one teenage boy and two adolescents (3.91 equivalent adults) would receive about $67 in aid. Since the maximum coupon allotments would need to be altered to reflect the financial burden (in terms of food expenditures) faced by unit-consumer families, the total outlay of federal funds for the FSP may increase, decrease, or remain the same. The important point is that with such a refinement, distribution is made more efficient (aid is extended to those who need on the basis of that need) as well as more equitable (family units of like composition are treated alike). A similar argument could be based solely on the distribution of food coupons to a single family unit as it moves through its life cycle.

In order to make this proposal functional, current expenditure levels would need to be established for a specified diet based on unit-consumer families. This could presumably be accomplished with the data used to establish the current standards table. Also, a new price chart based on unit-consumers would need to be established. Applying the results of a unit-consumer scale (Table 1) to the federal food stamp price chart [10], such a chart could be obtained simply by extrapolation. Local food stamp employees could then be provided with a rather simple form (such as Table 2) or a set of standardized tables to facilitate their calculation of unit-consumers within specific participant households.

It is important to note that such a revision need not imply that present procedures be altered extensively. Rather, current procedures could be held

Table 2. Hypothetical unit-consumer calculation chart

Category	Number of persons	Scale Coefficients*	Number of unit-consumers
1. Adult (age 20 or older)	______ ×	1.0 =	______
2. Male (age 15 to 20)	______ ×	.77 =	______
3. Female (age 15 to 20)	______ ×	.69 =	______
4. Adolescent (age 9 to 15)	______ ×	.57 =	______
5. Child (age 5 to 9)	______ ×	.59 =	______
6. Child (age 3 to 5)	______ ×	.46 =	______
7. Infant (age 0 to 3)	______ ×	.46 =	______
Total Number of Unit-Consumers (rounded to nearest 1/10th)			______

* Scale coefficients are taken from Price [10].

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[4] Recent research at Purdue supports this claim. When both methods of estimation were applied to the same data, the resulting scale coefficients were similar to each other and those reported in Table 1. See [1] for more detail.

essentially intact and only the price chart and the number of coupons issued to a participant family be changed to reflect explicitly the number of household members and the age-sex composition of the unit receiving aid.

It could be argued that such equivalence scales should be based on some predetermined dietary level rather than average purchasing behavior (expenditures) as are those presented in this paper. Since the current FSP does not generally restrict or encourage the purchase of any food commodity, it appears to this author that scales estimated from dietary levels would not necessarily serve to increase the nutritive value of the FSP participant family diets. It is true that participant families must use coupons to purchase food, but any food (and food in any form) is allowed.[5] If one subscribes to the concept of relative income developed by Duesenberry and others, it seems reasonable to assume that increasing the relative food purchasing income of the poor would elicit a behavioral response such that poor families with food coupons would be expected to purchase a diet as high in nutritive value as the average income family not participating in the program. This, however, remains as a testable hypothesis.

Conclusions

It is recognized that public programs which seek to alter the current distribution of income or in some way guarantee a minimum level of subsistence to all members of a society must combine economic feasibility with operational ease. In an effort to maintain operational ease and avoid public misunderstanding, the current FSP appears to be operationally designed with certain built-in inequities. In an era of high food prices, such inequities are subject to increasing public criticism. Public distribution programs must be made more efficient and more horizontally equitable. A FSP revision which would provide for the allocation of food coupons on the basis of both the number of persons in the household as well as the age-sex composition of the receiving unit appears to be such a proposal and deserves our serious attention.

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[5] The exception of course, is imported foods. The exact wording of the legislation is as follows: ". . . any food product for human consumption except alcoholic beverages, tobacco, those foods which are identified on the package as being imported and meat and meat products which are imported . . ." [11, p. 14103].

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THE VALUATION OF INCOME REDISTRIBUTION IMPACTS*

Water resource projects affect both the level of income and its distribution; therefore, when a water resource project is purchased, society buys both the additional income generated (which is and has been evaluated in the traditional cost-benefit analyses) and the redistribution of income generated by the project. A recognition of this latter purchase has come with the reformulation of the principles and standards for evaluating water resource projects that is currently in progress.

> In addition to their effects on the three objectives described above [national economic development, environmental, and regional development], most water and land resource plans have beneficial and adverse effects on social factors. These effects reflect a highly complex set of relationships and interactions between inputs and outputs of a plan and the social or cultural setting in which these are received and acted upon. These effects will be fully reported in the system of accounts for each alternative plan.
>
> With emphasis on their incidence or occurrence, beneficial social effects are contributions to the equitable distribution of real income . . . . [11, p. 24164]

Recognition of this jointly produced good, income redistribution, has generated a problem of valuation, i.e., determining how many other goods and services society is willing to forego in exchange for the income redistribution impact of a project. Placing a value upon this good is a different problem than that of valuing the electricity or irrigation water produced by a project. Income redistribution is a public good [10], the latter two products are private goods. Market price information can aid in estimating the value of additional private goods, but it is nonexistent for public goods.

Congress has the ultimate responsibility for valuing (national) public goods. In such valuation Congress is aided by consultants, reports, and hearings. The question, then, is what information can best aid Congress in making its decision. This paper addresses itself to this problem and, in the process, identifies and examines the determinants of the value of a redistribution impact.

The Determinants

Economics literature and logic suggest that the value of an additional unit of income redistribution will depend upon the following conditions:

1. The tastes of the people (assumed to be constant through time).
2. The current level and combination of goods and services produced and their distribution among people.
3. The method whereby redistribution is effected.
4. The horizontal and vertical equities of the redistribution.
5. The cost of the least-cost alternative way of effecting a comparable or superior redistribution.[1]

These determinants are evaluated below in terms of their potential aid to Congress in judging the value of an income redistribution. In this examination the justification for including each element of the list is presented.

Tastes of the people; and level, combination, and distribution of goods and services

The first item—tastes of the people—is included because the people purchase the redistribution with their resources, which are made available through congressional appropriation. Congress has the responsibility of representing the people, i.e., the tastes of the people. The second item—level, combination, and distribution of goods and services—is included because one corollary of demand theory is that the rate of substitution between goods is a function of the existing combination of the goods.

As the level of goods and services changes and/or the distribution of income changes, the value of additional units of redistribution will probably change also. Redistribution of income may be a superior good (income elasticity of demand positive). The trend in welfare legislation together with the trend in real income may imply a positive income elasticity.

Method of redistributing income

The method of redistributing income is included because redistribution impacts that are identical except with respect to the method of redistribution may be different goods as far as society is concerned. This possibility has been expressed in economics literature. ". . . size of the economic pie and its division may not be the only factors of concern to the community—the method of slicing the pie may also be relevant" [8, p. 63]. "The community may prefer to redistribute by providing income in kind . . . or by giving employment . . . as against cash support" [9, p. 804]. In addition, the employment tests in

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[1] To this list might be added the timing of the redistribution. If the recipients can transfer future benefits to the present using "the market rate of interest," it is the present value that is relevant, not the timing. Benefits that come through change in land prices are an example of this case. Consumers' surplus accruing to reservoir recreations, however, may not be so easily solved. See [2].

welfare legislation, the food stamp plan, and housing subsidies are all consistent with different methods being sufficient to generate different public goods.

Water resource projects and other types of investment have the potential of affecting both the size and distribution of future income. Such projects can affect the income of individuals by inducing changes in (1) relative prices and/or (2) money incomes. These changes occur as the projects change the supply of consumption goods and/or factors of production.[2]

An increase in the supply of a consumption good will, assuming demand is constant and not perfectly elastic, lower the price of the good.[3] This decrease will have associated with it an income effect which results from the individual having a command over a larger set of goods than before the price decrease, *ceteris paribus*. A measure of this income effect is the compensating variation of income that could be extracted from the individual such that his level of well-being remains as it was originally (Hicks' compensated variation of consumer's surplus).

A water resource project can cause a change in the money incomes of individuals in the following ways: (1) the project can induce changes in taxes paid; (2) the factors of production generated by the projects can be sold at a price less than the market price; and (3) the increased supply of factors generated by the project can induce changes in the prices of other factors.

A tax levied by a water conservancy district would be an example of a project-induced tax while corporation or individual income taxes used to finance the project probably are not. These taxes probably would have occurred in the absence of the project. An example of the second item is irrigation water from federally financed water resource projects. This water is frequently sold to land owners for less than the market price. In this example, the land owners are beneficiaries of special purchase rights.

A project-caused change in the supply of a factor such as irrigation water can be expected to shift the demand curves for other factors of production. Factors with supply curves that are less than perfectly elastic will experience a change in price, and their owners will experience a change in wealth and income. In the case of full-service irrigation water, it is conceivable that only land will experience an induced price change.

The redistribution effect of each source should be reported to Congress separately, since society may prefer certain sources over others even if the dollar amounts of redistribution are the same. A dollar's worth of redistribution coming through a change in the price of labor, or through a change in the rental on land, or through consumers' surplus for reservoir recreationists may not be equivalent, *ceteris paribus*.

Equity of income redistribution

Equity, from one viewpoint, is by definition an important feature of an income transfer. This viewpoint holds that the purpose of the transfer is to generate an equitable distribution of income. Thus, before judging the desirability of any income redistribution effected by a water resource project, Congress must evaluate the equity of that redistribution. This evaluation requires attention to both horizontal and vertical equity.

Horizontal equity calls for people with like circumstances to be treated alike; vertical equity calls for a desirable relative treatment of persons with unlike circumstances.[4] Horizontal equity demands that if one person deserves to be helped or benefited, then another characterized by the same set of circumstances deserves the same help.

Authors who have written about the effects of water resource projects upon income distribution have ignored horizontal equity and concentrated upon vertical equity. They report income redistribution impacts of water resource projects using only income class data.[5]

The problem with ignoring horizontal equity and concentrating upon vertical equity is that, in a system where both types are relevant, vertical equity cannot exist without horizontal equity. This statement can be proven assuming that society can assign optimal treatments to all sets of circumstances (current income, wealth, age) and using a precise definition of vertical equity. Vertical equity exists if, for any paired comparison of people in unlike circumstances, the two treatments are judged by society to have a desirable relationship.[6] First, for a system where both equities are relevant, the difference between the optimal treatments for any two different sets of circumstances will have a unique sign and magnitude. If this uniqueness were lacking, then two individuals could have the same circumstances but different treatments; hence, horizontal equity would be absent.

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[2] This analysis covers only the direct effect. It does not attempt to analyze the construction effect or the indirect effect. The construction effect would depend upon what was assumed to be given up to make funds available for construction. The demand for some goods will go down when the funds are transferred to construction of the project. This may cause an increase in the demand for some factors and a decrease for others. Whether or not the indirect effect is relevant depends upon whether national or regional effects are being measured.

[3] The price effect will occur whenever the induced change in price is perceptible. The change in the price of electricity probably would be imperceptible, but the change in the price of reservoir recreation to local residents probably would be perceptible.

[4] The set of circumstances would include those items that society deems to be relevant. They might include: current income, wealth, and age.

[5] See, for example, [3, 5, 6, 7].

[6] This definition like the one above stresses the importance of the individual.

Next, assume a system where vertical equity exists and both equities are relevant. To see the implications of these assumptions, define A to be a set of people with one set of circumstances and B to be a set of people with a different set of circumstances. Also, let A_1 be a randomly selected person from A and B_1 and B_2 be similarly selected from B. The assumptions imply that

$$T_{A_1} - T_{B_1} = T_{A_1} - T_{B_2} \tag{1}$$

and

$$T_{B_1} = T_{B_2} \tag{2}$$

where T_{A_1}, T_{B_1}, T_{B_2} are the treatments of A_1, B_1, and B_2, respectively. Equation (1) follows from the uniqueness of optimal treatment differences, which is implied by both equities being relevant; and the assumption that vertical equity exists, i.e., actual treatment differences equal optimal treatment differences. Finally, equation (2) says that horizontal equity exists, proving the initial proposition.

To use only income class data to judge the equity of a redistribution impact when horizontal equity does not exist is to say that classes of people are important but individuals are not. If one person in a class is taxed and another subsidized, and the amounts are equal, this is neutral or unimportant. If the standard deviation of benefits within a class is large or small with total benefits constant, this likewise is neutral or unimportant. Since research [1, pp. 57–61] has indicated that water resource-induced impacts lack horizontal equity, ignoring intraclass effects can lead to nonequivalent items being classified as equivalents, given that individuals are important.

When horizontal equity is absent, the equity of a redistribution impact would have to be judged by comparing transfers between all individuals. If, however, the number of people involved is large, such data would be impossible to generate and digest. It is suggested, therefore, that data for the following items relative to *each income class* (or set of circumstances) and each method of redistribution[7] will go a long way toward describing the redistribution effect:

(a) total transfers
(b) number of recipients
(c) average transfer (transfer per recipient)
(d) standard deviation of the transfer among recipients
(e) range of the transfer among recipients
(f) percent of individuals who are not recipients.

Least-cost alternative

If society pays more for a given set of goods than their cost by the least-cost alternative way of producing the goods, the purchase is non-optimal. It is non-optimal in the sense that more of some goods can be made available without reducing the quantities of others. Thus, since there are alternative ways of redistributing income, the cost of the least-cost way of generating a comparable or superior redistribution impact is the maximum amount that society can rationally pay for a water resource redistribution impact. In addition, the cost of some inferior and some superior redistribution impacts[8] should theoretically be of interest to the decision makers. Society can be expected to be willing to trade between redistribution impact and cost.

Congress should be presented with the cost of the least-cost identifiable comparable or superior redistribution impact. In addition, the cost of similar impacts using alternative methods[9] of redistribution should also be reported, leaving Congress to decide which are the inferior, comparable, and superior impacts. With this information, Congress will be in a better position to decide how much society is willing to pay for the water resource redistribution impact.[10]

One additional point is that if equity and alternative cost are the only relevant features of a redistribution impact, then the least-cost comparable or superior impact probably will be generated by taxes and cash transfers. The main costs of such redistributions are the "excess burden" of the price distortions generated by the taxes and transfers. These costs are estimated by Musgrave to be small per dollar of transfer [9, p. 804].

Summary

In conclusion, as recommended by the Water Resources Council, data describing the redistribution impact should be displayed for Congress to evaluate. It has been argued that the value of the impact depends upon: (1) how the transfer is effected, (2) the horizontal and vertical equities of the transfer, (3) the size of the transfer, and (4) the cost of the least-cost alternative way of effecting a comparable or superior transfer. Specific recommendations are made that should facilitate congressional judgment of redistribution impacts with respect to these items.

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[7] If, in addition, items such as race, age, family size, and/or geographic region are deemed relevant, such data should be presented for the relevant additional categories.

[8] Inferior, comparable, and superior redistribution impacts are defined to be less, equally, or more desirable impacts, respectively, when the tastes of society (but not costs) are taken into account.

[9] A part (probably the majority) of the cost of most of these alternative transfer systems that change relative prices will be the "excess burden" generated by the price distortion. See [4].

[10] The topic of this section has an implication for the opportunity cost of funds. Since private investment in research and development and in capital goods redistribute income via these same means, the opportunity cost of capital should take this into account. The market rate of interest will not take the associated redistribution of income into account; hence, the market rate of interest is a biased estimate of the opportunity cost of funds

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AAEA'S UNSUNG HEROES, UNGLAMOROUS ROLES, AND UNMET CHALLENGES

Our Association does not fail to memorialize its distinguished members, young and old. At annual meetings a platform full of awardees hear their accomplishments lauded. This *Journal* faithfully reminds who our Presidents have been and who have been named Fellows. In informal ways achievements are acknowledged.

It is so true as to be trite that various less conspicuous praiseworthy performances go largely unpraised. Any list of unsung heroes would surely include:

1. All members of committees that select recipients of AAEA awards. Lots of theses, reports, and supporting materials must be read. Baker remarked recently on the burden of performing this service [2].
2. Judges of public speaking and debate contests in the undergraduate program. Tucked away in some remote corner, these contests draw both sponsors and judges away from the program sessions. Most of us, however, willingly perform this self-denying service.
3. Reviewers of manuscripts submitted for publication in this *Journal,* particularly those who take the trouble to offer editorial suggestions to the author.
4. The Employment Services committee, many department chairmen, and others who make the employment service a useful undertaking.
5. The Secretary-Treasurer and his assistant, who bear a heavy responsibility year after year. Other officers, including the perpetually overloaded editors, may be equally dutiful, but they rotate more often.
6. The hosts at each annual meeting.

From their beginning and throughout their history, our AAEA and its predecessor organizations have depended on the volunteer services contributed by their members. Each proposal to commercialize internal activities was dispelled by the size of the bill. Our strength and growth will continue to depend on the anonymous persons who perform well in unglamorous roles.

Nor has the gamut been run. Unfulfilled opportunities remain, unmet challenges beckon. The three diverse proposals offered here begin with the familiar call to disciplinary self-examination and end with near-alarm about protecting the statistical base to our collective existence.

1. Evaluation of our performance as a profession and a discipline. Occasional critiques find their way onto annual programs and into this and other journals. Sometimes they are directed more to forecasting our professional prospects than to reporting candidly how faithfully we have performed as scientists. Any established discipline runs the risk of drifting into self-serving habits. Are we in danger? It would be interesting to compare judgments offered by young and veteran members.
2. Professional guidance to graduate students. The hypothesis underlying this suggestion is that the agricultural economics establishment miscommunicates the kinds of careers that are most promising. The mistake made is to glamorize certain sub-areas of agricultural economics, overloading those with candidates even as others are underfilled. My hunch is that resource economics and development economics have been oversubscribed recently. Reportedly, farm management is undersupplied. Also, calls frequently come to me from agribusiness firms asking for recommendations of economists competent in commodity analysis and feasibility studies. If these random indications are reliable, the question arises whether we can provide some kind of feedback mechanism to improve market-evaluation guidance for career selection.
3. Attentiveness to public support for research and for statistical services. Recent annual meetings have programmed sessions on both topics (cf. [1] and the discussions that followed). Nevertheless, our profession has either taken public support for granted or has believed it could not or should not concern itself with such mundane matters. The attitude is unwarranted. In the past year one statistical base for our profession came under serious jeopardy. The instance was the move that threatened to politicize the Census Bureau, together with the Commerce Department's arbitrary decision to cancel the 1974 Census of Agriculture. Our AAEA Statistical Committee, and James Bonnen in particular, are among our unsung heroes as they and others successfully protested the scuttling of the Agricultural Census. How many among us lent a hand?

It is hardly necessary to add that the statistical problem is not just one of keeping numbers coming, but also of protecting their quality. The quality of data of the Census of Agriculture, for instance, surely has suffered in recent years. In some respects structural changes in the agriculture-agribusiness complex make accurate statistical reporting more difficult than before.

It is just possible that some of the unpublicized efforts of unsung heroes in unglamorous roles are vital to the continued strength of our profession. It is possible too that if various of the unmet challenges are not met better in the future, we all will be self-victimized by our neglect.

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SUGGESTED SECTORS FOR INPUT-OUTPUT MODELS OF RURAL AREAS

Estimates of total impacts on an economy from changes in economic activity are widely believed to be useful in regional economic analysis. A prime restriction in applying input-output models to project total impacts is the cost of collecting primary data for the many sectors of a potentially large model. A recent study by Doeksen and Little, however, offers the important conclusion that ". . . size of the model has very little or no effect on impact input-output (I/O) analysis" [2]. If this is true, then critical questions for a low cost aggregate analysis of rural areas are: what are appropriate sectors of a rural area model, and what are appropriate techniques for estimating parameters of the model?

Need for Appropriate Sectors

Agricultural economists should collectively invest some time and energy in definition of appropriate I/O sectors for rural areas. The current Standard Industrial Classification (SIC) which has been the aggregation scheme for a number of studies is frequently misused to describe the functional form of the rural economy. The four-digit level of the code provides too many sectors for a small model, and the two-digit code, SIC 20, is so broad that it covers most of the rural agribusiness functions. The hypothesis of this paper is that the appropriate agribusiness sectors are those that produce inputs and provide marketing functions for farming. These are trade flows observed in the rural area and, therefore, can be subjected to sampling as an appropriate technique for estimating model parameters.

Indeed, most of the functional agribusiness sectors of the rural area are under constant scrutiny by market researchers and extension marketing economists. Given a useful and recognized aggregation scheme with well defined data requirements, many seemingly unrelated projects in a research program could be contributing data to a more comprehensive I/O study.

Defining Agribusiness Sectors for a Rural Area

In addition to contributing studies, recent experience by Miernyk [6] indicates that sampling is a viable approach to I/O studies. Sample survey techniques were used rather inexpensively in Georgia to define the model in this paper. For the basic concepts of I/O one should consult a standard reference such as Dorfman, *et al.* [3].

The endogenous sectors of the Georgia agribusiness model included 12 agribusiness sectors, one farming sector, and one all-other industries sector. The industries in each agribusiness sector produced a commonly recognized class of products and could generally be characterized as producing almost exclusively for farming or purchasing from farming. The 12 agribusiness sectors were defined as follows:

Agricultural Chemical Manufacturers—firms that manufacture agricultural chemicals, fertilizers, pesticides, and herbicides.

Dairy Product Processors—processors of milk, ice cream, and cheese.

Field Crop Processors—firms such as cotton gins, tobacco processors, grain processors, peanut dryers, and others.

Farm Machinery and Equipment Manufacturers—firms that manufacture tractors, combines, trailers, and parts for farm use.

Farm Machinery and Equipment Retail Sales and Services—hardware and farm supply stores that specialize in machinery and equipment and other durable goods.

Agricultural Supply, Retail Trade, and Services—hardware and farm supply stores that specialize in seed, feed, fertilizer, insecticides, and similar production expenses.

Feed Manufacturers—manufacturers of feed for livestock, poultry, and other domestic animals.

Lumber and Wood Products—such firms as logging camps and sawmills.

Food Processors—firms that process meat and crops used for food.

Livestock Markets—stockyards and livestock auctions.

Nursery Production, Sales, and Landscaping Services—the growing and retail sale of nursery products and landscaping services.

Agricultural Credit Associations—firms that deal primarily in farm credit.

Industries in each sector were aggregations of four-digit SIC classes. Firms were classified into sectors on the basis of the principal product or service provided. The four-digit SIC numbers that make up each of the 12 Georgia Agribusiness sectors were delineated by Langley [5] who also compared them with the I/O sectors constructed by the Department of Commerce [13].

Since a simplified definition of the agribusiness firm used in this study can be expressed as an establishment that sells to or buys from agriculture, the farming sector becomes a very vital sector of the model. This definition of agribusiness falls short of a more general definition usually attributed to Davis and Goldberg [1] but is felt to offer operational significance for sampling agribusiness firms in a study of rural areas. In other words, at this level one avoids the question of whether a firm that does business with an agribusiness firm is *also* an agribusiness firm.

The survey of the agribusiness firms in this model did not include all data required to complete an input-output table. Primary inputs to farming and all-other industry; interindustry transactions in all-other industry and farming; sales to final demand of all-other industry and farming; and total output of all-other and farming were estimated from secondary sources [4, 7, 8, 10, 11, 12]. Details on complete methodology for constructing the tables are reported by Langley [5]. In general, the procedure was to supplement sample data with trend adjusted primary inputs and total output from census materials and to adjust data from other I/O studies (i.e., national and regional) for the remaining coefficients.

Results and Implications

An I/O model of the rural area emphasizing agribusiness can be characterized as having a low density transactions matrix. With the exception of farming and all-other industry, purchases are mostly from farming and primary inputs with very little trade flow among sectors; sales are principally to all-other industry and final demand. In general as interdependence among sectors in an I/O model diminishes, one expects multiplier effects to diminish also. However, the effect of leakages through regional imports also has a significant effect on multiplier size. Thus, in a rural agribusiness model constructed from sampling one loses some of the interdependence in the economy, but should gain good unbiased estimates of imports from the survey data.

According to Doeksen and Little [2], however, multipliers from small models are comparable to

Table 1. Total output multipliers for similar endogenous sectors of two input-output models of Georgia

Sectors	SIC Class	Agribusiness Output Multipliers from Sampling—1969	Output Multipliers from a Location Quotient Model—1970	Agribusiness Imports from Sampling—1969	Imports from a Location Quotient Model—1970
				(Percent of Total Purchases)	
Agricultural Chemical Manufacturer[a]	2871–3, 2879	1.40		24	
Chemical Products	281, 286–9		1.40		34
Dairy Product Processor	2022, 2024, 2026	2.25		1	
Dairy Products	202		1.96		13
Field Crop Processor	2041, 2045, 2051–2, 2091, 2096	2.10		31	
Food Products	205–7, 209		1.47		35
Farm Machinery & Equipment Manufacturer		1.10			
Farm Machinery & Equipment Sales		1.00			
Agricultural Supply Sales		1.00			
Feed Manufacturer	2042	1.98		24	
Grain Mill Products	204		1.59		48
Lumber & Wood Processor & Sales	24	1.51		0	
Wood Products	24		1.43		29
Food Processor	2011, 2013, 2015, 2031–35, 2037	2.17		14	
Meat Products	201		1.92		18
Canned, Preserved Food	203		1.68		33
Livestock Markets		1.52			
Nursery Product Sales		1.57			
Agricultural Credit Associations		1.48			
Farming		1.92			
All-Other Industries		1.17			

[a] Name and description of a sector of the 14 sector agribusiness model is followed on an indented line with the name and description of a comparable sector of a 50 sector I/O model by Schaffer and associates.

those obtained from larger models, suggesting that less description of interdependence is not a serious factor in estimating multipliers. But, regardless of the size of the model, size of the multipliers would always be a function of imports.

This hypothesis was tested by comparing multipliers of the agribusiness model with those obtained in an I/O model of Georgia by Schaffer, Laurent, and Sutter [9]. They constructed a model by use of the location quotient method with adjustment by sampling data. Their model contained 50 sectors, some of which were similar to sectors in the agribusiness model. Their model contained more linkages among sectors, and this might be expected from a larger model. There were also large differences between estimates of imports from sampling and imports from the location quotient method.

The Schaffer model had the higher import estimates in every comparable sector, Table 1. Thus, their multiplier estimates should be lower if there are no effects due to model size. This expectation is confirmed by comparing multiplier results. In every case the value of the total output multiplier in the Schaffer model was less than or equal to the comparable agribusiness multiplier, Table 1.

Sector definitions as shown in Table 1 were different in most cases and, thus, there should be some expected difference in multiplier values. The relationship of import estimates to the differences, however, seems clear. Differences in import estimates also suggest that this area of estimation is crucial in small area studies. One can perhaps adjust technical coefficients from state and national models by budgeting for differences in production functions, but there is no logical way to account for the level of imports except by observation. Thus, at least this level of sampling should be a part of all small model studies.

Finally, the major differences between the 50 Sector Georgia model based on Commerce Department definition and the 14 sector agribusiness model point up the difficulty in adapting existing studies to rural areas. Multi-county planning groups in rural areas are becoming increasingly involved in aggregate economic planning, and it behooves the agricultural economists to provide them with a meaningful and consistent set of sector definitions that will facilitate surveys for small models and one that will also serve as a master file for existing marketing and extension work.

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USE OF LINEAR PROGRAMMING IN CAPITAL BUDGETING WITH MULTIPLE GOALS: COMMENT*

Candler and Boehlje's [1] suggestion for capital budgeting with non-commensurable outputs is of special interest to economists concerned with problems involving goals which cannot be valued in monetary terms.[1] The purpose of this paper is to show that while their procedure may overcome some of the problems inherent in other approaches to the non-monetary goal problem, it frequently will not lead to a well-conditioned maximum under the assumptions which they stated.

The problem that they deal with is as follows: Find the $1 \times k$ vector of activities and investment levels x which maximizes the objective function:

$$(1) \qquad Z = z(g_1[x], g_2[x] \ldots\ldots g_n[x])$$

subject to:

$$(2) \qquad Ax \leqslant b$$

and

$$(3) \qquad x \geqslant 0$$

and some elements of x integer

where $g_j(x)$ is the jth goal function which can be expressed on an additive scale, $j = 1, \ldots, n$.
x is the $k \times 1$ vector of investment alternatives and investment levels.
Z is "some function, probably nonlinear, of the level of individual goal functions" [1, p. 326].
A is a $m \times k$ matrix of the cash flows and technical coefficients of the investment alternatives.
b is a $m \times 1$ vector of restraints on the cash flows.

It is assumed that the gradient vector of Z can be subjectively determined by the decision makers for any particular solution and that a local optimum is the global optimum.

Essentially the Candler-Boehlje proposal involves a modification of the vector maximum problem of finding "efficient" vectors where the $k \times 1$ vector x^* is efficient if it is feasible and there is no other feasible vector x^{**} such that

$$g_j(x^{**}) \geqslant g_j(x^*) \text{ for all } j$$

$$g_j(x^{**}) > g_j(x^*) \text{ for some } j$$

where $g_j(x)$ = the jth goal function; i.e., no alternative feasible vector x^{**} can increase the value of one or more of the goal functions without decreasing the value of at least one of the other goal functions. Generally, solving the vector maximum problem involves finding all of the efficient points. It is impossible to determine the optimal solution without additional information concerning the preferences for different goals. Candler and Boehlje claim that their proposal avoids the necessity of finding and displaying all of the efficient solutions and also provides a means for finding the optimal solution. Before discussing the theoretical foundation of their suggestion, the three basic steps will be reviewed:

Step 1. Provision of tentative estimates on an additive scale of the effects, a_{ij}, of alternative investments, x_j, on previously unquantified goals, $g_j(x)$; and estimates of an initial set of relative weights $(\lambda_j, j = 1, \ldots, n)$.

Step 2. The problem is then formulated in a modified linear programming framework as shown in Table 1. The computer then calculates an initial efficient solution given the initial set of estimated weights $(\lambda_j, j = 1, \ldots, n)$.

Step 3. If the decision makers feel the initial solution is an improper mix of the various goals, they indicate "the direction of the relative change in the weights which they think would lead to an improved solution" [1, p. 330].

The last two steps are repeated until the decision makers feel a solution is superior to all adjacent solutions. Then, by the assumption that (1) is quasiconcave, this yields the optimal solution.

Their suggestion appears to overcome many of the difficulties facing economists who deal with non-monetary goals.[2] Using their approach, there is no need to derive tenuous shadow-prices for outcomes lacking direct market valuations in order to maximize a single objective function measured in dollar terms. Neither is it necessary to avoid attempting to make the outcomes commensurable by presentation of a matrix of consequences for each investment alternative and investment level. There is also no necessity of arbitrarily selecting minimum target levels for all but one goal. This frees researchers to investigate more carefully the substantive impacts of alternative activities. It frees policy-makers from the necessity of understanding complex or confusing qualifications

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* The author is indebted to Richard H. Day for comments on an earlier draft of this paper.

[1] For a critical review of the alternative approaches to this problem with governmental projects, see Freeman [2, pp. 565–572].

[2] Freeman [2, pp. 574–578] has made a proposal similar to that of Candler and Boehlje for governmental decisions. There are several differences in these two suggestions: (1) Freeman assumes that the decision makers will know which projects are feasible; (2) Freeman's adjustment of weights occurs only in the initial stages; and (3) Freeman is seeking a preference function which can be applied to future decisions while Candler and Boehlje are seeking only a means of selecting the optimal choice from a given set of alternatives.

Table 1. Model of the simplex tableau for a multiple goal problem

Objective: Max			0	0	0	…………	0	λ_1	λ_2	………	λ_k
Restraint	B		Activities					Goal Functions			
			x_1	x_2	x_3	…………	x_n	$g_1(x)$	$g_2(x)$	…..	$g_k(x)$
1	b_1	≥	a_{11}	a_{12}	a_{13}	…………	a_{1n}	0	0	…..	0
2	b_2	≥	a_{21}	a_{22}	a_{23}	…………	a_{2n}	0	0	…..	0
:	:		:	:	:		:	:	:		:
m	b_m	≥	a_{m1}	a_{m2}	a_{m3}	…………	a_{mn}	0	0	…..	0
Goal 1	0	≥	$-a_{p1}$	$-a_{p2}$	$-a_{p3}$	…………	$-a_{pn}$	1	0	…..	0
2	0	≥	$-a_{q1}$	$-a_{q2}$	$-a_{q3}$	…………	$-a_{qn}$	0	1	…..	0
:	:		:	:	:		:	:	:		:
k	0	≥	$-a_{r1}$	$-a_{r2}$	$-a_{r3}$	…………	$-a_{rn}$	0	0	…..	1

implied by the assumptions behind derived shadow-prices and also from information overkill in the matrix approach. In fact, Candler and Boehlje claim that by using their iterative approach, *"we can feel our way towards an optimal capital budget without ever explicitly defining the decision-maker's preference function"* [1, p. 330].

Unfortunately, their procedure is unlikely to achieve this under the assumptions they made. Although no discussion of the theoretical foundation of this procedure was given in their note, it is clear that it is based on the following vector maximum theorem:

If x^* is an efficient point, then there exists a vector $\lambda = (\lambda_1, \lambda_2, \ldots \lambda n)$ with $\lambda \geqslant 0$ and $\Sigma_j \lambda_j = 1$ such that the maximum of the function $Z = \Sigma_j \lambda_j g_j(x)$ in the set of all x satisfying $h_i(x) = 0$ and $x \epsilon X$ is achieved for $x = x^*$ where X is a closed and convex set and $g_i(x)$ and $h_i(x)$ are concave functions of x [3, p. 216].

This is illustrated graphically in the case of two competing goals in Figure 1 by x and the ratio λ_2/λ_1. Here x represents continuous variables, and thus this maps into closed and convex opportunity set in this two dimensional goal space. While x^1 is an efficient point, we cannot determine the optimal efficient point without the objective function Z. If x^2 is the optimal point and the decision maker can determine the gradient vector of Z (i.e., how to change λ_2/λ_1), they will eventually converge to x^2. For example, if the initial estimate of the weights is $(\lambda_2/\lambda_1)^1$, it is assumed that the decision maker

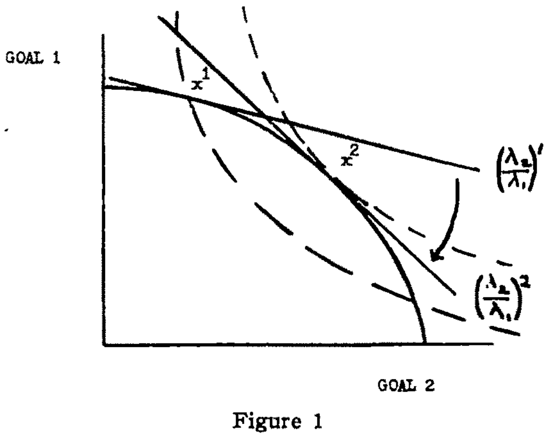
GOAL 1
x^1
x^2
$\left(\frac{\lambda_2}{\lambda_1}\right)^1$
$\left(\frac{\lambda_2}{\lambda_1}\right)^2$
GOAL 2

Figure 1

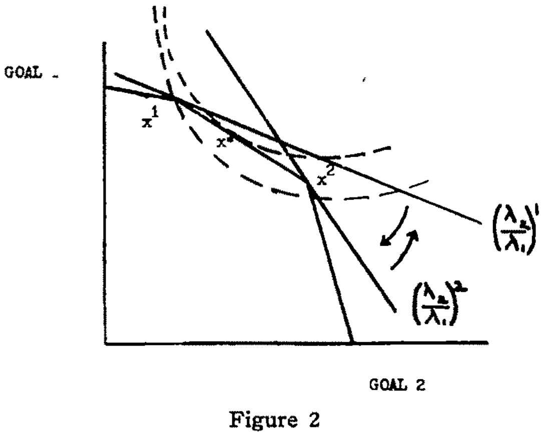
GOAL -
x^1
x^*
x^2
$\left(\frac{\lambda_2}{\lambda_1}\right)^1$
$\left(\frac{\lambda_2}{\lambda_1}\right)^2$
GOAL 2

Figure 2

will indicate changes in this ratio until $(\lambda_2/\lambda_1)^2$ is reached. But if some of the x are integers and Z is nonlinear as Candler and Boehlje assume, then their procedure may never converge to the optimal solution.

If the restraints are linear inequalities as in (2), then the suggested procedure may lead to cycling between corner solutions in an attempt to zero in on the desired efficient point. This is illustrated in Figure 2. At the initial solution x^1, the decision maker's subjective estimate of the gradient indicates that λ_2 should be increased relative to λ_1. This leads to the weights $(\lambda_2/\lambda_1)^2$ and the solution x^2. Now the gradient of Z indicates that λ_2 should be decreased relative to λ_1 and any change sufficient to move the solution from x^2 toward the optimal solution x^* takes us back to x^1. It is clear that even though the gradient of Z can be obtained, their procedure will cycle between x^1 and x^2. In a simple problem like this one cycling will be recognized immediately and little will be lost. But this solution procedure is for decision problems with many noncommensurable outputs or goals, and thus cycling may not be recognized quickly.

The problem which Candler and Boehlje formulated assumed that some x are integers and Z is probably non-linear. If x is an integer and the relationship between $g_j(x)$ and x is linear, then the goal functions also assumes integer values. Convergence cannot be guaranteed in this case unless all the feasible points are extreme points falling outside the hyperplane connecting any other feasible points. An example of the more typical case with interior integer points is shown in Figure 3. Here both Goal 1 and Goal 2 are functions of the integer variable x. It is again obvious that the Candler-Boehlje procedure will not converge to x^* but will simply cycle between x^1 and x^2.

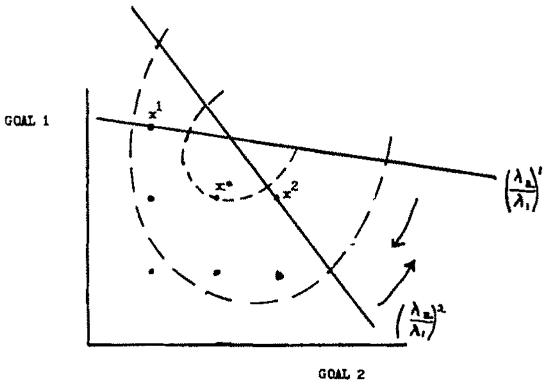
GOAL 1
x^1
x^*
x^2
$\left(\frac{\lambda_2}{\lambda_1}\right)^1$
$\left(\frac{\lambda_2}{\lambda_1}\right)^2$
GOAL 2

Figure 3

If only one goal, say Goal 2, is a function of the integer variable and the other is a function of a continuous variable, the feasible region would be similar to that in Figure 3 with three vertical lines terminating at x^1, x^2, and x^*. Again it is obvious that cycling would occur here in the same fashion as in the previous case.

Thus while the Candler-Boehlje procedure can solve a restricted class of multiple goal problems, its use will demand careful investigation of the nature of the control variables and goal functions. For many problems, it appears that we will still have to resort to estimating shadow-prices and displaying matrices of non-commensurable goals.

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USE OF LINEAR PROGRAMMING IN CAPITAL BUDGETING WITH MULTIPLE GOALS: REPLY

George Morse has identified situations in which our suggested iterative decision making procedure would approximate, rather than find, the optimum solution. We are grateful for his comments and for redrawing attention to our paper. Having acknowledged that our procedure is not perfect, we maintain that for many practical situations it is likely to be the best available.

Our paper addresses itself to the question: Given a concrete problem involving several goals, and a decision making group whose objective function is unknown, how do we proceed? Our approach is to incorporate a *set* of goals in a linear programming model, to assign initial relative weights to these goals, and then to use an interactive procedure between the model and the decision group to improve upon the goal weights.

Addressing ourselves to Morse's Figure 2, as the number of constraints is increased, the efficiency frontier will be closer to a continuous transformation function, and the cycling problem will become less severe because the cycle will occur around a very small linear segment that contains the optimum solution. With respect to the number of goals, cycling would be recognized, even in n-dimensions, as soon as a previously found solution was felt to be equal to or better than the new solution. Given that cycling has been recognized and that it occurred because the new solution had gone too far in the gradient direction, we would suggest asking the decision making group for limits on the units of goal 1 they would trade for goal 2.

Addressing ourselves to Figure 3, it is a simple matter to modify an integer code so that previously found integer solutions will not be reselected. However, with the extreme curvature of the (unknown) objective function in Figure 3, it has to be admitted that:

(a) Many iterations would likely be needed before the optimum solution happened to be found, and

(b) we would not know even then that the optimum solution had been found.

However, where the optimal solution is not an extreme point on a convex hull of feasible points as illustrated in Figure 3, the display method would require enumeration of all feasible solutions.

Be our guest!

[*Received December 1973.*]

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Reviews are listed alphabetically by authors.

Book Reviews

Adelman, M. A., *The World Petroleum Market*, Baltimore, The Johns Hopkins University Press for Resources for the Future, Inc., 1972, xviii + 438 pp. ($22.50 cloth, $5.95 paper)

If Adelman's work were to be judged by its predictions, it would not fare well. But it is an indication of the strength of the analysis that Adelman's concepts help explain why his predictions are faulty. The book is required reading for any economist concerned with energy problems and will remain so for some time.

The economic structure of the petroleum industry is described according to type of activity, cost of production, and industrial organization. The petroleum industry consists of six sub-industries. These are exploration, development and production, two transportation industries (pipeline and tanker), refining, and marketing. In Adelman's view the seven major multinational companies do not constitute a working oligopoly in any of these industries, nor does their vertical integration imply monopolistic practices for the petroleum industry in its entirety.

Adelman believes the corporate goal of the industry is maximum present value of profits (p. 2) and that a monopoly price would be higher with lesser output than prices would be in a competitive industry (p. 14). We should recall that this is economic theory, intended to produce observable implications about behavior. It is equally possible to develop a theory of monopolistic output maximization subject to a profitability constraint. This would imply the exact opposite: lower price and higher output with average cost pricing. Theory in and of itself is neutral with respect to economic behavior. To the extent that a theoretical statement is said to be reality, then to that degree it becomes dogma and loses its power of explanation. Example: (A) monopoly produces high price, restricted output, and excessive profits, (B) it is observable that petroleum industry profits are not excessive, and that output has grown while real prices have declined, (C) therefore the petroleum industry is not monopolistic. This sort of thinking neatly steps over the possibility that economic structure may have caused excessively high levels of consumption and production.

The empirical content of the discussion of market concentration is to be found in the use of Herfindahl coefficients and "firm equivalents," the inverse of the Herfindahl coefficient. These Herfindahl coefficients are defined as the sum of the squares of the shares of market sales over all firms in the market. They have the propitious quality that if a market has n firms with an equal $1/n$ share of sales, then the coefficient (i.e., the sum of $1/n$ squared) is $1/n$. Adelman finds that the coefficients show declining market concentration (p. 82). While interesting, the discussion is not particularly oriented towards structure-behavior relationships which may be derived from the study of joint ventures. Example: Standard Oil of New Jersey is the largest U. S. multinational and is one of the three major partners in the Aramco concession. Aramco administers the Saudi Arabian boycott of the U. S. Standard Oil of New Jersey (Exxon) is also one of the three major partners in the Alaskan North Slope field. The recent Congressional approval of the Alaskan pipeline (making Exxon a beneficiary) was prompted by the boycott which Exxon helped administer. Truly the Lord taketh away and giveth back! Adelman is of course aware of such information but has chosen not to include such details in his discussion of structure.

Nor has he concerned himself with the substantial oil company ownership of natural gas, coal, and uranium reserves and production.

The strength of the book is its analysis of costs in the various regions and sectors of the industry. He estimates the cost of U. S. production at about $1.25 per barrel (in 1968 prices), Persian Gulf oil at 10–20 cents per barrel, African oil at 15–30 cents, and Venezuelan oil at 50 cents per barrel. Since Persian Gulf oil is the dominant source in world markets, the long run supply price for any area is equal to the long run supply price for the Persian Gulf plus any freight advantage to major markets. Thus the long run supply prices are 20 cents per barrel for the Persian Gulf, 45–60 cents for Africa, and 60 cents for Venezuela. This long run supply price is the price necessary to meet costs and return on capital. Thus investment cost per barrel equals the present value of future revenues, or $I = \int P * Q(t)dt \int \exp(-rt)dt$ over the planning horizon of T years. The cost of capital is the annual interest rate r. Since production declines over the life of a facility at an annual decline rate a, $Q(t) = Q(0) * \exp(-at)$. Hence the long run supply price is $I/Q(0) \int \exp[-(a+r)t]dt$. At this point the exposition becomes confused. A "Present-Barrel-Equivalent Factors" Table is provided (p. 51) to show discount factors of the combined interest and decline rate. The first column is incorrectly labeled as "$a + r$"; it is in fact $[(1+a)(1+r) - 1]$. The *PBE* factors are not derived from the definition used above and throughout the text (i.e., $\exp[-(a+r)t]$), but the values in this table are actually calculated from $\int(\exp - [(\ln[(1+a)(1+r)])t])dt$. This cumbersome form is intended to capture the "nominal continuous" nature of the process. The gain in complexity may be offset by the loss in comprehension: Adelman seems to misread his basic table on page 57 where he does not discern the error in labeling and calculates capital cost per barrel in the U. S. at $1.048 rather than the apparently correct $1.098. Further, the table seems to have been prepared with insufficient care to the rounding of significant digits. The reader should consider himself forewarned.

In discussing reserves the author explains that proved reserves have "been developed for production by the drilling and connecting of wells and associated facilities. It is the total of planned production from facilities already installed and paid for" (p. 26). At first glance this would seem to qualify the seriousness of declining reserve/consumption ratios in the U. S. Adelman reports estimated remaining oil-in-place at 300 billion barrels in 1968, far in excess of the 30 billion barrel proved reserves. It would seem, then, that simply sinking more wells would increase the reserve/consumption ratio. But the problem is that this oil-in-place is generally not in the easily accessible underground fields of the Southwest. Alaskan oil, tar shale oil, and Northeastern offshore oil will all be substantially more expensive, perhaps two to three times higher than present fields.

This problem returns our attention to the Persian Gulf where easily accessible underground fields contain one trillion barrels, give or take a few hundred billion. It is Adelman's contention that these large reserves and the low supply price provide the basis for continued bargaining between producing countries, the companies, and consuming countries. In particular he argued that the OPEC countries could not act as monopolists, that (p. 260), "The worry about 'access' assumes something very queer indeed: that ALL of the producing countries will join in to refusing to sell to some particular buyer—for what strange motive is never discussed. One catches hints that such a boycott will favor one consuming nation over another. Why a producing country should engage in this expensive pastime is never discussed, although it takes only one other country, with a desire for gain, to cure this irrationality."

Equally comforting is his prediction of continued declining prices (p. 8).

The breadth and depth of the book wholly overshadow cumbersome arithmetic and faulty predictions. It is required reading for understanding energy economics.

Duane Chapman
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Barnard, C. S., and J. S. Nix, *Farm Planning and Control*, New York, Cambridge University Press, 1973, viii + 550 pp. ($22.50)

The opening pages of this volume emphasize the importance of the control function in managing farm firms. Several stages in farm planning and control are identified. Control is described as a series of regular checks on the entire system to detect deviation of the actual from the planned outcome and the taking of corrective action when it is within the manager's power to do so. The remainder of the initial section of this intermediate farm management text discusses the basic economic principles and concepts used in farm planning as well as the organization of land, labor, and capital resources. Discussion of capital includes a limited description and evaluation of investment analysis. Computation of machinery and building costs is outlined. Use of breakeven analysis in selecting the size of machine and source of machinery services is illustrated thoroughly. The chapter on labor treats the planning of labor and work simplification and also includes a very useful treatment of incentive payments and personnel management.

The second part of the book considers the management of individual crop and livestock enterprises. The analysis includes a detailed coverage of selecting the least-cost combination of two feeds, as well as the most profitable rate of feeding for alternative time and output assumptions, including batch production. While such topics as the seasonal aspects of livestock production and costs of raising replacements are discussed rather thoroughly, very little emphasis is placed on the planning of crop production.

A comprehensive treatment of farm planning using budgeting, programmed budgeting, and linear programming comprises the third part of this volume. The introductory chapter of this section does an excellent job of relating the production possibilities curve to planning with enterprise gross margin (cost and return) estimates. The underlying assumptions are given and related clearly to the graphical analysis. The procedures required to apply each of three methods are explained and illustrated. The authors also do a thorough job of contrasting the usefulness of the three approaches in farm planning.

The final part is concerned with control of resources and enterprises. Two of the three chapters in this part discuss farm records and an analysis of completed records. Although relatively little has been mentioned about the control function between the first and last chapters, the discussion of methods of control is certainly worth reading. The procedures to use in maintaining both financial and operational control throughout the year are stressed. The similarity of the recommended approach to management by objectives is outlined. Thus the two functions, planning and control, are shown to overlap and complement each other in managing the farm business.

Although this volume is lengthy and relatively comprehensive, several important topics are omitted. The general area of long-run planning is only mentioned in passing. When it is mentioned, the implicit assumption is made that the firm is in its growth phase. Consideration of long-run planning for the entry, growth, and exit phases of the firm's life cycle would be a useful addition. Another omission is the failure to recognize and discuss the problems associated with livestock waste management, pesticide use, and other environmental concerns that currently enter into many farm planning and control decisions.

Perhaps the major weakness of this volume for use as a text in an applied farm management course is the lack of a straight-forward, integrated explanation and illustration of how to prepare cost and return estimates for crop and livestock alternatives. An explanation of estimating machinery costs, numerous examples of using economic principles in selecting enterprise input and output levels, and the importance of fixed and variable cost concepts is given at various points in the text. But the uninitiated student, even after a careful reading of the text, will find it difficult to pull the procedure together and prepare the estimates required for the farm planning procedures discussed.

The authors avoid the use of any mathematics in the text except simple arithmetic and two-dimensional graphs. Even the simplest of algebraic relationships has been relegated to appendices of the chapters. This effort results in the need for lengthy explanations, reduced clarity, and a less rigorous treatment of many issues than could otherwise be achieved. This problem is particularly noticeable in the discussion of the economic principles, the development and use of breakeven formulas, replacement analysis, and investment analysis.

Cash flow analysis is introduced relatively early in the volume and its potential use is discussed. However, the examples are very simple and little explanation is given as to how projected cash flows can be prepared. Thus the importance of projected and actual cash flows in financial planning and control is not adequately developed.

Because the book is written for use in Great Britain, all of the examples, illustrations, and terminology used are for the agriculture in that area. Barnard and Nix also include a number of rules of thumb as a way of summarizing their research findings for agriculture in Great Britain on capital use, reducing machinery costs, the economic size of fields, and other topics. Both of these characteristics limit the usefulness of this book as the single text for a farm management course in other areas of the world.

The sections of this book that will be of most general use in teaching farm management deal with integration of the planning and control functions, labor organization, and farm planning. Instructors will want to have their classes read these sections as well as others. The volume will also serve as a useful reference book for farmers and farm managers. It is indeed a useful addition to the literature in agricultural economics.

VERNON R. EIDMAN
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Berg, Alan (portions with Robert J. Muscat), *The Nutrition Factor: Its Role in National Development*, Washington, D. C., The Brookings Institution, 1973, viii + 290 pp. ($8.95 cloth, $3.50 paper)

Mr. Berg is convinced that malnutrition is a major world problem—"not the centerpiece of development, but . . . an important part" (p. 5)—and that governments should be persuaded to give nutritional programs a much more prominent place in their plans. He firmly differs with those who believe that problems of malnutrition will correct themselves as incomes rise. "The consumer is least capable of evaluating the nutritional component [of food], and of recognizing the degree to which meeting . . . other objectives . . . may deprive him of the health he assumes he is acquiring. Such considerations argue strongly for governmental intervention" (p. 30). Chapter 4 provides a first-rate review of the weakness of the causal chain between increased national income per capita and improved nutrition: that it result in a significant increase in the income of the poor; that this lead to an increase in the family's food purchases; that increased purchases result in improved nutritional composition of foodstuffs coming into the household; and that this improved nutritional potential be shared with the nutritionally vulnerable members of the family (p. 42). For a variety of reasons, any one of these links may not hold, the possibility becoming greater as one goes down the chain.

The body of this book provides a useful review of the various ways in which governments have intervened or might intervene in order to improve the nutritional quality of diets, of the multifarious determinants of the costs and benefits of such interventions, and some account of actual attempts in this direction, most of them disappointing. Berg also argues that "nutrition is becoming a more relevant policy issue—and remedial action more feasible—as countries are relieved of the pressure of an inadequate food supply" (p. 1). He accordingly provides in Chapter 5 a useful overview of the nutritional effects of recent agricultural changes.

The author considers three general approaches to nutritional enhancement—education (Ch. 6), new foods (Ch. 8), and public feeding programs (Ch. 10)—and finds problems and possibilities with all of them. These chapters are well balanced and well informed. They are predominantly concerned with the problems of families that buy their own food, although there is an intriguing discussion in the special chapter on India of using things like salt and tea as carriers for certain nutrients. (It is hard to see how they could help much with protein consumption, which is *the* nutritional problem of most of the world).

Finally, the book calls for a new approach by government planners to problems of malnutrition involving a broad commitment based on "awareness of the problem, a commitment to do something about it, and implementation, and representing "a quantum jump in the nature of their response" (p. 199). This would be achieved by systematic nutritional planning and analysis, calling on the skills of specialists in "operations, communications, logistics, administration, and economics" (p. 206) rather than those of "biochemists, pathologists, food technologists, pediatricians, and other nutritionists" who have heretofore dominated the field. In effect, he calls for the development of a new discipline of the practice of nutrition as opposed to the science of nutrition.

The Nutrition Factor is an important statement. It would have much greater impact if Berg had shown more restraint in the opening chapters where he is "selling" nutrition, and elsewhere in the more substantive chapters where, from time to time, he permits enthusiasm and dedication—and proof by vigorous assertion—to substitute for reasoned argument. The economist will also occasionally be put off by Berg's handling of certain economic considerations. And the excessive reliance on Indian experience at times becomes irritating.

The purpose of the book is to direct attention to a major problem of human well being, to examine in a popular, understandable way what instruments are available to correct it, and to call for a broad-scale, balanced, and efficient attack on the total problem. The book does that, and rather well.

William O. Jones
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Collinson, M. P., ***Farm Management in Peasant Agriculture: A Handbook for Rural Development Planning in Africa,*** **New York, Praeger Publishers Inc., 1972, xxvi + 444 pp. ($22.50)**

Upton, Martin, ***Farm Management in Africa,*** **London, Oxford University Press, 1973, xiv + 341 pp. ($17.50)**

Authors Collinson and Upton, sometime colleagues at the University of Reading, after extensive professional experience in Africa, have written books which have been critically needed for teaching farm management in universities located in developing, tropical countries. Teaching in the tropics of Africa, South America, and Asia has been done under great handicap These books do not provide all that is needed, but they do make significant strides in that direction. Although written for use in Africa and directed toward those with farm management orientation, they will be of value to anyone with interests in peasant agriculture anywhere in the world.

Both authors start with the premise that agricultural economists working in peasant agriculture should place little emphasis on individual farm accounting and planning. Due to the homogeneity of farming systems within a geographic area, it is better to concentrate on understanding the representative condition from which recommendations can be inferred to a large number of farming units. The agricultural economist should also diagnose small holder farming situations in order to recommend and evaluate agricultural research and policy.

The title of the Collinson book may be inappropriate. It is somewhat more than a textbook in farm management and somewhat less than a handbook for rural development planning. It is organized into three parts: 1) Conditions in African Peasant Agriculture Affecting the Applications of Farm Management Techniques; 2) The Investigation Phase; and 3) Planning Extension Strategy and Content. One-half of the book is devoted to the second part.

The 16 page introduction is an insightful account of the activities of expatriate agricultural economists in Africa with interests in farm management and the reasons for their failure to have micro-relationships adequately incorporated in national plans. Much of the burden of the book is to outline and describe the procedures which would overcome these failures. To the extent that such failures have been due to inadequate and inappropriate farm family planning data, faulty assumptions about peasant behavior, a lack of understanding about the relationship between the peasant condition and managerial decisions, and the tendency for extension programs to lack content aimed at farmers' priorities, the book offers constructive proposals for overcoming them.

It is excellent in its pragmatic approach to investigations of rural problems in societies with a tribal structure (Part II). This section may very well qualify as a handbook. However, too many performance variables of a nonagricultural and intersectoral nature are merely alluded to or ignored to make the book a handbook for rural development planning. Nevertheless, planners should take Collinson's work seriously because he stresses points too frequently slighted in national planning efforts.

At the university teaching level this book should be used as a reference in courses dealing with development problems. Its use should not be restricted to teaching farm management. An index would have enhanced its usefulness.

Professor Upton's *Farm Management in Africa* takes the conventional principles taught in farm management courses and applies them to the equatorial African situation. Five chapters on the theory of production (Part 1) are followed by a discussion of the use of land, labor, capital, and management (Part 2) in agricultural production. Then, four chapters are devoted to data sources and analysis (Part 3) followed by a concluding planning section devoted to budgeting and linear programming analysis.

The lucid presentation of principles, appropriate examples from the local scene and the clear and concise mathematical appendices should make the book an attractive text for students and teachers of production economics in Africa. Whether or not the work will satisfy the needs of the farm management teacher will depend on one's definition of the appropriate scope for the subject matter of farm management. If the methodological base for farm management work is assumed to be production economics theory and if the primary problems of farmers are defined in terms of departures of the firm from an equilibrium specified by maximizing or minimizing a single objective function, then the book will be welcomed enthusiastically.

On the other hand, if farm management is viewed as the process of solving multi-disciplinary problems faced by farm families as both producers and consumers in an open and dynamic community system, then the book falls short. But this is not to fault the book; it is to fault the profession for treating the environment of the farm family as given, as we undertake the study of the farm firm under the name of farm management. If the major questions in farm management in peasant agriculture are not questions of resource allocation and efficiency in use, how much to produce and what technology to employ at the farm level, then we need to define the more significant problems, to know what theories have relevance, and to evolve the methodologies which will provide answers to help solve those problems. Until that is done, Professor Upton's text will be among the best farm management texts available today. Indeed, it should be of interest to farm management teachers who do not do their work in the LDC's.

In conclusion, even though both authors start and end at approximately the same place, they travel a slightly different road. Their works make useful and provocative companion pieces.

Warren H. Vincent
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Hightower, Jim, *Hard Tomatoes, Hard Times: A Report of the Agribusiness Accountability Project on the Failure of America's Land Grant College Complex*, Cambridge, Schenkman Publishing Company, 1973, xviii + 268 pp. ($9.50 cloth, $4.95 paper)

This book is not a typical, purportedly objective, academic treatise couched in nonemotive colorless language. The purpose of *Hard Tomatoes, Hard Times* is to bring attention forcefully to what the author believes to be the *failure* of the U. S. Land Grant System of Colleges of Agriculture, Experiment Stations, and Extension Services. "Although the land grant college complex was created to be the people's university, to reach out to serve the various needs of a broad rural constituency, the system has, in fact, become the sidekick and frequent servant of agriculture's industrialized elite" (p. 1).

The documentation of this assertion of failure occupies the remainder of the book following a concise history of the origin of the Land Grant System. Chapter II argues that the vast majority of research conducted is directed towards increasing the efficiency of agricultural production. In fact Hightower argues that less than 5 percent of total Experiment Station research is devoted to "people oriented" categories. Further, he argues the Land Grant System has created the mechanical revolution in U. S. agriculture and still continues to be dedicated to continuing the displacement of labor from agriculture, ignoring those it displaces and leaves behind. Further, charges Hightower, far too little attention has been paid to quality—quality of food, of housing, of communities, and quality of life for rural people.

The Land Grant Complex does not do all these things necessarily maliciously, it is just so closely connected with the USDA and big agribusiness that it thinks exactly as they do. Chapter III talks of interlocking nature of the research policy-making apparatus. Chapter V argues that the Land Grant-USDA community is so in-bred and insulated that no new ideas enter. Chapter VI documents the influence of agribusiness on the direction of land grant research through direct monetary support and by industry pressure. Chapter VII contends that the Extension Services deserve similar criticism for their service to the agricultural elite at the expense of the rest of rural America. The book concludes with a set of demands for full disclosure of activities, public discussion of goals and priorities, and a congressional investigation of this $750,000,000 complex.

What of the validity of the charges outlined above? Author Hightower uses by and large published reports, from the Cooperative State Research Service (CSRS) and its ponderous reporting system, CRIS, from the Agricultural Research Service (ARS), and from several state experiment stations and extension services. As an anonymous and threatened land grant administrator has said, "we were crucified with our own data." In addition extensive interviews are reported. It is clear that the author set out with a particular point of view to present and sought to document those conclusions. In some cases strong conclusions are drawn from limited and fragmentary evidence. For example, the fact that most land grant administrators have at least one degree from a land grant institution does not necessarily prove that they all think alike nor that they are participants in some grand conspiracy to serve as handmaidens of big agribusiness. One could spend much time on other specific points, but it would not overturn the fact that the evidence presented does support the proposition that the Land Grant establishment has pursued, to the near exclusion of other objectives, the god of efficiency. Hightower does not point out, however, that so has the rest of American society with equally questionable results.

Sometimes we may find it difficult to look in the mirror and believe what we see. *Hard Tomatoes, Hard Times* at least offers us a partial opportunity to do so and learn from it. It raises questions similar to some that have been raised recently within the system as to relative priorities and calls on us to examine our public responsibility carefully. It serves no purpose to be defensive about the book because it can be used as a stimulus to correct what faults exist. The book should be required reading for every member of the Land Grant Complex because it gives a clear picture of what at least some other people think of this particular establishment.

ALEX F. MCCALLA
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Hopkin, John A., Peter J. Barry, and C. B. Baker, *Financial Management in Agriculture*, Danville, The Interstate Printers and Publishers, Inc., 1973, x + 459 pp. ($10.75)

Financial management in agriculture is increasingly recognized as playing a larger and more important role in the management of the farm firm. Yet most of the managerial literature in agricultural economics continues to deal with the problems of production and management. However, many of the more complicated problems of the farm firm are related to the acquisition and control of resources and the management of cash, credit, debt, and taxes.

This book centers on the financial problems of the agricultural firm with particular reference to the sole proprietorship. In general the book deals with the principles of financial management adapted to the agricultural firm and their application. Most financial management texts deal only with the problems of the large corporate firm. The main emphasis of the authors is on investment decisions and financial control.

The book is divided into five major sections. The first section investigates the nature and scope of financial management, looking first at the management process, then in turn at the organizational areas of the firm, how time lies at the heart of financial management, and introduces the pertinent tools of financial management.

The second section looks at the institutional setting for financial management and surveys the more important institutional forces which relate to financial management: the legal environment in which farm business management decisions are made, the process of transferring money from savers to borrowers, and the financial institutions operating within the agricultural credit market.

The third section relates to the firm setting for financial management. Here the authors make major contributions beyond traditional farm management methods in developing concepts and tools to be used by the manager in the acquisition and use of resources, in controlling the performance of the business, and in relating financial decisions to production and marketing decisions. Their use of after-tax concepts of income, cash flow, and the evaluation of investments through time preference concepts makes a welcome departure from tradition.

Initially, in the third section, the authors review financial accounting tools and illustrate their use in analysis and in forward planning. They introduce time and its impact on managerial decisions, introduce the concept of time preference, and develop the concepts of discounting and compounding into the dynamic setting of the farm firm and the life of the manager. Chapters on growth investigate the incentives to growth, the constraints to growth, the role of financial leverage, liquidity management, and the conflict between leverage and liquidity. Chapters on "Capital Budgeting for Investment and Financing" develop the framework for evaluating prospective investments under alternative methods of acquiring control of assets. As returns to be measured, the authors use net cash flow from the business. The major criterion they use for valuing returns is the present value method. A portion of this section is devoted to the cost of capital.

The fourth section looks at alternatives in resource control and their evaluation. They discuss the special financial instruments, institutions and policies which have been established in financing and controlling three broad categories of resources: land, depreciable assets, and annual operating inputs. Particular emphasis is given to coordination with the total cash flow of the business.

The final chapter in the fourth section is devoted to alternative forms of business organization. Although it is an adequate discussion and is integrated into the remainder of the book, it lacks the hard-hitting quality of the other chapters.

The fifth and last section treats three special topics of financial management: the tools and the use of these tools to analyze and control an ongoing farm business, tax management, and estate management. The book is a definite contribution to the literature in the field of farm financial management. It successfully integrates financial management and production and marketing management for the agricultural firm. It is very understandable and would be extremely useful in undergraduate farm management and finance courses. It would also be a very useful reference for professionals in those fields.

R. N. Weigle
University of Wisconsin-Madison

James, P. G., *Agricultural Policy in Wealthy Countries*, London, Angus and Robertson, 1971, xiii + 368 pp. ($3.75 paper)

Dr. James obviously has studied the agricultural policies of many countries, and judging by his treatment of agricultural policies in the United States, his presentations are thorough and accurate. However, the book includes more than description and appraisal of these policies. The first 100 pages deal with a broad range of agriculturally related subjects and could be a standard section in any textbook on the economics of agricultural production. Similarly, some 17 pages in the chapter on Agricultural Policy in the United Kingdom could be standard fare in a textbook on agricultural marketing with examples from the U. K.

According to the author, National Governments tend to have similar policy objectives related to agriculture. These include achieving more efficient use of resources, enhancing the welfare of farmers, stabilizing prices for the benefit of producers and consumers, and defending domestic producers against foreign competition.

Each of the major countries pursues these objectives in a slightly different manner depending on the nature of local problems. In Australia, where farm incomes are high relative to nonfarm incomes, the emphasis is on improving farming efficiency, and price stability. Also, the implementation of national policy is carried out largely through the State governments by encouraging the States to adopt enabling legislation. This method is in contrast with most other countries where programs are carried out by the National Government through established government offices or through a system of federally sponsored boards, commissions, authorities, and committees.

The legal basis for farm policies differs substantially among countries. According to the author, American farm policy is peppered with formal legislation. Conversely, British producers regard the Agricultural Act of 1947 as a large umbrella to protect them all against the effects of economic storms. Under it the British Government may do almost as it wishes and claim the action is justified in the "National Interest."

In reviewing policies of the several countries, much of the book is devoted to descriptions of programs with little attention to appraisal of the program objectives or their adequacy in attaining those objectives. These tendencies are particularly apparent in the treatment of the Agricultural Policies of the United Kingdom. For example, the establishment, composition, and functions of the Home Grown Cereals Authority for the United Kingdom are described in considerable detail (pp. 188–191), but this reviewer was unable to discern the purposes of these activities or whether the Authority was successful in accomplishing them.

The four chapters describing national agricultural policies of "wealthy" countries provided a good historical reference of programs that have been applied in a variety of circumstances. The chapter on Agricultural Policies of the European Economic Community includes brief reviews of individual country policies as well as the broader policies of the ECC.

But for this reviewer chapter 8 on Agricultural Policy and Structural Reform and chapter 9, Reflections on Agricultural Policy, were the most interesting. In these chapters the author made his own appraisal of the problems of agriculture and the kinds of programs needed to deal with them. Although most countries have attempted to aid their farmers through improving the pricing mechanism or raising prices, the author sees the problem as the need for adjusting size of farms to use emerging technology more efficiently. Some countries, e.g. Sweden and Luxembourg, have programs to assist farm people in attaining these objectives by consolidating fragmented small holdings and scattered tracts into economic units and to prevent them from later reverting to small holdings again. These programs are described adequately and interestingly.

One of the problems of a book on policy is that policies or at least the programs for implementing them continue to change. The most recent statements regarding policies in the United States, for example, are those encompassed in the Agricultural Act of 1965. For some other countries, the descriptions of programs are more up-to-date, but none more recent than 1970. However, some of the programs in effect in 1970 continue to date.

Some of the statements regarding policies in the non-English speaking countries apparently were translated from their native languages, and their clarity suffered as a consequence of too-literal translation. Even the difference in technical terms in the U. S. and U. K. causes some ambiguities in the absence of a glossary. Apparently "compounders" are an important influence in pricing grains in the United Kingdom. But the function of a compounder is not clear.

Although the book is longer than it needs to be because of the inclusion of some extraneous material, the author has performed a worthwhile service in bringing together in one place descriptions of the agricultural policies employed in wealthy countries.

James Vermeer
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Kelso, Maurice M., William E. Martin, and Lawrence E. Mack, *Water Supplies and Economic Growth in an Arid Environment: An Arizona Case Study*, Tucson, The University of Arizona Press, 1973, xviii + 327 pp. ($8.50 paper)

Seldom have the objectives of a specific but comprehensive research project been as fully attained as in the project that culminated in the publication of this book. Under the overall direction and leadership of Professor Kelso, this decade-long project has examined the many-faceted water oriented economy of Arizona, seeking to determine if limited water supplies in that arid state are likely to establish barriers to long-run viability and growth. The authors recognized at the outset that a simplistic set of answers would not result from examination of a complex set of physical, biological, economic, and institutional variables. They have, none the less, produced a book that poses real questions, reports on complex findings, and clearly sets forth definitive conclusions that will be useful for years to come. Furthermore, it should serve as a general model for research organization and reporting that could help advance research productivity in the field of resource economics. The effectiveness and impact of the study are not likely to be confined to Arizona.

The book is organized and presents information according to the general research plan of the study. The authors pose issues or specific problem areas and then present information designed to answer a progressive series of questions that outline the nature of the study: What are the dimensions of the water problem in an arid area? How can the many aspects of the problem be best analyzed for short- and long-run time periods? What restraints are presented by current legal and political institutions? What might happen as water supplies become increasingly scarce? What are the current and possible future relationships between agriculture—the principal water using sector of the state—and other economic sectors activities? What can be done to optimize defined sets of future economic conditions if and when water resources become scarce for particular uses?

In reporting the study, the authors present knowledge and method without letting their solid methodology and theoretical soundness interfere with a smooth flow of informative results. This report does not present extensive methodological recipes—the reader interested in theoretical framework and justification of models used must consult the many thesis reports and published articles contained in the bibliography that document this study. The lack of extensive and specific citation may be viewed by some as a weakness of the final report. But the research oriented fraternity should not be unduly upset as they are accustomed to digging a bit for information and in most instances will insist on consulting primary technical reports and sources anyway.

The majority of readers of the book will be grateful to the authors for presenting an uncluttered report. Much of the traditional obeisance to ritualistic research reporting is observed only in the breach. Thus the extent, clarity, and significance of results obtained are not marred by form or appearance. Prose is clear and concise. Tables and graphs are clear and explicit. Sufficient statistical data are presented to characterize problem areas and issues studied.

This book should prove useful to a wide audience in years to come. Undergraduate students in resource economics courses can easily read and comprehend the problems presented, the general approaches used in studying the problems, and the conclusions reached. They will continue to need other books for presentation of basic theory and methods of analysis appropriate to resource economics. *Water Supplies and Economic Growth* is not a primer of resource economics—but neither does it pretend to be such. The constant application and use of economics in the overall study, however, make this report an excellent companion for case study to whatever texts and lecture material individual professors may prefer.

Graduate students may at first be somewhat skeptical of the study because of the lack of specific theoretical, quantitative, or institutional window dressing. However, the rigorous and tight organization, the clear and crisp prose, and the logical as well as definitive conclusions should impress any reader as to the solid merit of the study. This book should, then, also be an excellent companion in graduate seminars where students should not be bothered by a near absolute absence of documented "security blanket" references to bodies of received knowledge. As mentioned earlier, all researchers in the field of resource economics should find this book a useful help-mate in structuring, conducting, and reporting empirical research.

Finally, the readability and relevance of *Water Supplies and Economic Growth* should also guarantee it a well deserved place on the desks and book shelves of legislators, administrators, managers, and just plain citizens interested in water resource issues. It will be of interest and value to anyone concerned over possible adjustments to the prospects of increasing scarcity of those natural resources we have all too long viewed and used as though they were without limit.

Professors Kelso, Martin, and Mack are to be congratulated on this report. It should long serve as an excellent model for structuring and reporting on research in the field of resource economics.

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University of California—Davis

McCoy, John H., *Livestock and Meat Marketing*, Westport, The Avi Publishing Co., Inc., 1972, ix + 465 pp. ($21.00)

Professor McCoy stated in the preface that his book is intended for undergraduate students with an acquaintance with elementary economic theory. No doubt the book has a far wider range of interest than that of undergraduate students, and most of the text can be readily understood with little formal economic training. The book is exceptionally well written and easy to follow with adequate data and documentation. Most of the elementary theory necessary to understanding the content is provided in Chapter III. This book should be a part of the library of everyone with a serious interest in the livestock-meat industry including the specialized livestock producers, dealers, packers, wholesalers, and retailers. It should be an especially useful reference for those in the animal science and meat science professions.

Livestock and Meat Marketing covers the entire vertical continuum of the livestock-meat industry from the primary producer through the retailer. The book is heavily slanted toward the descriptive and factual aspects of the industry. Professor McCoy's book demonstrates a complete and accurate knowledge of the livestock and meat industry and the literature pertaining thereto. In the chapter (V) on "Meat Consumption and Related Demand," McCoy adequately explains the difference between consumption (available supply or disappearance) and demand. This seems to be one of the more difficult concepts for the non-economist. Events that unfolded during 1973 are especially pertinent to this concept in that meat consumption (available supply) declined in the United States coinciding with a rapid expansion in demand.

Events of 1973 also demonstrate the foresight of Professor McCoy in his inclusion of a chapter on meat substitutes and synthetics, although the manuscript was completed sometime earlier. McCoy warned the livestock-meat industry of the futility of attempting to thwart substitutes and synthetics by legal action. Relatively high meat prices will tend to encourage substitutes and extenders. About the only recourse the meat industry has is to insist on accurate labels on all substitute products. The text was concluded with an exceptionally strong chapter on "The Shape of the Future." McCoy concluded that the trends toward large scale producing units, large scale specification buying of meat, and more formal vertical coordination of the industry through vertical ownership and contracting are likely to continue. However, environmental interests may constrain the size and location of producing units. Contrary to prevailing misconceptions, this book emphasizes the dynamic, progressive, and efficient nature of the United States livestock-meat industry.

The serious student (and professor) of the economics of the livestock-meat industry with the emphasis on problem solving quantitative techniques would need to supplement this text. This is not a serious limitation as most texts are supplemented and a useful bibliography is provided at the end of each chapter. Some of the more sophisticated techniques including econometric models of the livestock-meat sector, spatial equilibrium models, multidimensional transhipment models, and simulation techniques are not included in this text. Also, Professor McCoy's book will likely need to be updated in a relatively short time period with respect to estimates of the parameters of the market and issues confronting the livestock-meat sector.

McCoy's *Livestock and Meat Marketing* will certainly fulfill its intended purpose as an undergraduate text and will also provide a useful reference to all segments of the livestock and meat industry.

JOSEPH C. PURCELL
University of Georgia—Griffin

Musgrave, Richard A., and Peggy B. Musgrave, *Public Finance in Theory and Practice*, New York, McGraw-Hill Book Company, 1973, xv + 762 pp. ($12.50)

Public Finance in Theory and Practice is a marriage of something old, something new, and something borrowed. The authors have covered a wide range of problems dealing with the theory and operation of the public sector. Most of these problems are traditional, some are contemporary, but all require an understanding of the relevant institutions and economic systems if they are to be resolved satisfactorily through collective action.

The book is divided into eight parts addressing the following topics: (1) fiscal functions and institutions, the theory of social goods, and fiscal politics, (2) the structure and evaluation of expenditures, (3) the structure of revenues generated through various taxes, (4) tax and expenditure incidence, (5) the effects of taxation and expenditure on efficiency and aggregate activity, (6) stabilization, (7) fiscal federalism, and (8) the specific issues of welfare, the negative income tax, social security, pollution, and the international and development aspects of fiscal actions. The chapters within these sections vary in their degree of institutional and analytic detail. The authors provide a reader's guide at the beginning of each chapter expressing their objectives in presenting the material, how students with different backgrounds may approach that material, and often some additional sources for the proverbial "interested reader." The book is suitable for an undergraduate course in public finance, and the breadth of material covered permits flexibility in selecting an appropriate micro-macro-institutional mix.

An obvious comparison of the present text is with Richard Musgrave's earlier text, *The Theory of Public Finance* (1959). Examination of both will show them to share a similar philosophy of the public sector as well as the method of analysis for certain topics. These similarities are particularly manifest in Chapter 1 dealing with the allocative, distributive, and stabilization functions of government; in Chapter 8 dealing with the philosophy of a "good" system of taxation; and in the four chapters dealing with stabilization. Chapter 5 on the structure and growth of public expenditures, Chapter 30 on international public finance, and Chapter 31 on the fiscal alternatives in developing countries also draw heavily from Richard Musgrave's *Fiscal Systems* (1969) and from Peggy Musgrave's work on the international aspects of taxation. There is, then, a good deal of earlier work by both Musgraves incorporated into their present text.

The authors have made a conscious effort to present both the theory and the application of theory to problems of the public sector. Chapter 6 presents a compact treatment of some of the principles of expenditure evaluation. This is followed by a chapter containing some case studies (highway construction, outdoor recreation, and education) and a brief discussion of the PPB system. Economic theory is also applied to an analysis of the negative income tax, social security, and environmental policy in part eight. It is in this balancing of theory and applied analysis—as well as in parts three and four which describe the structure and incidence of the income, corporation, property and wealth, payroll, and sales taxes—that the text offers a new approach to the study of public finance. The incidence of the aforementioned taxes, especially the corporate tax, has been a controversial subject, and the authors have cited supplementary and often divergent analysis in footnotes and at the end of most chapters.

There are several chapters within the text which borrow from other authors. Chapter 3 on the theory of social goods derives its substance from such classics as Lindahl's "Just Taxation: A Positive Solution," Samuelson's "The Pure Theory of Public Expenditures," and the more recent work of J. G. Head and H. Shibata. Chapter 4 on fiscal politics contains a restatement of Arrow's work on voting rules and the economic analysis of the political process as found in the works of Buchanan and Tullock, Anthony Downs, and Mancur Olson, Jr. Part seven dealing with fiscal federalism borrows the ideas on optimal community size as advanced by J M. Buchanan, on the spatial equilibrium of local public goods as developed by C. M. Tiebout, and from a recent text by W. E. Oates.

The success of most texts in economics will depend, in part, on how well the author relates concepts and problems to an underlying body of theory. Richard and Peggy Musgrave have attempted this in the diverse field of public finance which spans traditional micro-economic and macro-economic theory as well as the fiscal institutions of federal, state, and local government. Such an undertaking must quickly bump up against an upper bound on page length which excludes discussion of some topics and limits the depth of analysis on others. Richard and Peggy Musgrave have done an admirable job in the face of this constraint. Students of public finance will benefit from their effort. To a great extent *Public Finance in Theory and Practice* represents the perspective of a man who has made significant contributions to that field. For this reason the book is also a worthwhile addition to the libraries of practicing economists.

JON M. CONRAD
University of Massachusetts

Books for listing in this section should be sent to the Book Review Editor (see inside front cover for address).

Books Received

Alexander, G., and O. B. Williams, eds., *The Pastoral Industries of Australia: Practice and Technology of Sheep and Cattle Production,* Sydney, Sydney University Press, 1973, xv + 567 pp. Price Unknown.

Ballantine, John W., *The Human Side of Economics: And Its Significance for Enterprise Management,* Madison, Mimir Publishers, Inc., 1973, viii + 170 pp. Price Unknown.

Berthold, Theodor, *Die Agrarpreispolitik der DDR: Ziele, Mittel, Wirkungen,* Berlin, Duncker & Humblot, 1972, 295 pp. Price Unknown. Paper.

Champernowne, D. G., *The Distribution of Income Between Persons,* London, Cambridge University Press, 1973, x + 287 pp. $17.50.

Christy, George A., and John C. Clendenin, *Introduction to Investments,* 6th ed., New York, McGraw-Hill Book Company, 1974, viii + 688 pp. $12.95.

Coombs, Philip H., Roy C. Prosser, and Manzoor Ahmed, *New Paths to Learning: For Rural Children and Youth,* New York, International Council for Educational Development, 1973, x + 133 pp. $2.00. Paper.

Corty, Floyd L., and Lynn L. Pesson, *Institutional Development: The College of Agriculture in Malaysia,* Baton Rouge, Louisiana State University, 1973, x + 163 pp. Price Unknown.

Eckstein, Eleanor F., *Menu Planning,* Westport, The AVI Publishing Company, Inc., 1973, x + 318 pp. $16.00.

Folley, R. R. W., *Intensive Crop Economics,* New York, American Elsevier Publishing Company, Inc., 1973, ix + 331 pp. $17.00.

Ford, Marjorie Winn, Susan Hillyard, and Mary Faulk Koock, *The Deaf Smith Country Cookbook: Natural Foods for Family Kitchens,* New York, Macmillan Publishing Co., Inc., 1973, xiv + 352 pp. $7.95.

Harberger, Arnold C., *Project Evaluation: Collected Papers,* Chicago, Markham Publishing Company, 1973, xii + 330 pp. Price Unknown.

Harriss, C. Lowell, ed., *Government Spending & Land Values: Public Money & Private Gain,* Madison, The University of Wisconsin Press, 1973, xix + 239 pp. $10.00.

Johnson, Harry G., *The Theory of Income Distribution,* London, Gray-Mills Publishing Limited, 1973, ix + 292 pp. £6.75 Cloth, £3.25 Paper.

Johnson, Stanley, *The Green Revolution,* New York, Harper & Row, Publishers, 1972, xiii + 218 pp. Price Unknown. Paper.

Knight, Richard Victor, *Employment Expansion and Metropolitan Trade,* New York, Praeger Publishers, Inc., 1973, xvi + 110 pp. $10.00.

Kramer, Amihud, *Food and the Consumer,* Westport, The AVI Publishing Company, Inc., 1973, viii + 256 pp. $6.50.

Kramlich, W. E., A. M. Pearson, and F. W. Tauber, *Processed Meats,* Westport, The AVI Publishing Company, Inc., 1973, vii + 348 pp. $20.00.

Markham, Jesse W., *Conglomerate Enterprise and Public Policy,* Boston, Division of Research, Graduate School of Business Administration, Harvard University, 1973, xviii + 218 pp. $9.00.

Moore, John R., Sardar S. Johl, and Ali M. Khusro, *Indian Foodgrain Marketing,* New Delhi, Prentice-Hall of India Private Limited, 1973, xii + 188 pp. Price Unknown.

Moyer, D. David, and Kenneth Paul Fisher, *Land Parcel Identifiers for Information Systems,* Chicago, American Bar Foundation, 1973, xxiv + 441 pp. Price Unknown. Paper.

Odero-Ogwel, Lawi, and Eric Clayton, *A Regional Programming Approach to Agricultural Sector Analysis: An Application to Kenya Agriculture,* Ashford, School of Rural Economics and Related Studies, Wye College, 1973, 89 pp. £1.50.

Ofori, I. M., ed., *Factors of Agricultural Growth in West Africa,* Legon, Institute of Statistical, Social and Economic Research, University of Ghana, 1973, xii + 291 pp. Price Unknown. Paper.

Paauw, Douglas S., and John C. H. Fei, *The Transition in Open Dualistic Economies: Theory and Southeast Asian Experience,* New Haven, Yale University Press, 1973, xii + 306 pp. $12.50.

Paiva, Ruy Miller, Salomão Schattan, and Claus F. Trench De Freitas, *Brazil's Agricultural Sector: Economic Behavior, Problems and Possibilities,* São Paulo, Instituto de Economia Agricola, Secretaria de Agricultura, 1973, xvii + 451 pp. Price Unknown. Paper.

Potter, Norman N., *Food Science,* 2nd ed., Westport, The AVI Publishing Company, Inc., 1973, xiv + 706 pp. $15.00.

Rouveyran, Jean-Claude, *La Logique Des Agricultures De Transition,* Paris, Éditions G. P.

Maisonneuve et Larose, 1972, 277 pp. Price Unknown. Paper.

Russell, D. G., *Resource Allocation System for Agricultural Research,* Stirling, University of Stirling, 1973, xxii + 178 pp. £2.00. Paper.

Swamy, Subramanian, *Economic Growth in China and India, 1952–1970: A Comparative Appraisal,* Chicago, The University of Chicago Press, 1973, ix + 84 pp. $6.95.

Turnock, David, *Scotland's Highlands and Islands,* London, Oxford University Press, 1974, 48 pp. $2.50. Paper.

Van Arsdel, Wallace B., Michael J. Copley, Arthur I. Morgan, eds., *Food Dehydration: Practices and Applications,* 2nd ed., Westport, The AVI Publishing Company, Inc., 1973, xi + 529 pp. $28.00.

Van Dresser, Peter, *Development on a Human Scale: Potentials for Ecologically Guided Growth in Northern New Mexico,* New York, Praeger Publishers, 1973, xv + 116 pp. $10.00.

Wilcox, Walter W., Willard W. Cochrane, and Robert W. Herdt, *Economics of American Agriculture,* 3rd ed., Englewood Cliffs, Prentice-Hall, Inc., 1974, viii + 504 pp. Price Unknown.

Wildsmith, J. R., *Managerial Theories of the Firm,* New York, Dunellen Publishers, 1974, iv + 140 pp. $10.00.

Wong, John, *Land Reform in the People's Republic of China: Institutional Transformation in Agriculture,* New York, Praeger Publishers, Inc., 1973, xxiv + 319 pp. $20.00.

Zaman, M. A., *Evaluation of Land Reform in Nepal,* Kalhmandu, His Majesty's Government Press, 1973, xi + 124 pp. $4.00.

Announcements

ANNUAL MEETING
AMERICAN AGRICULTURAL ECONOMICS ASSOCIATION

Texas A & M University
College Station, Texas
August 18–21, 1974

Format of the 1974 Annual Meeting

Monday Morning, August 19

Welcome: James K. Williams, President, Texas A & M University

Presidential Address: "Agricultural Economics in the Mid-70's: Where Do We Go from Here?"
James Nielson, Washington State University

Invited Address: "Some Impacts of the Changing Energy Situation on U. S. Agriculture," Harold O. Carter and James G. Youde, University of California, Davis

Monday Afternoon, August 19

Topic: Energy and U. S. Agriculture

Chairman: Max R. Langham, University of Florida

Paper: "Petroleum for U. S. Agriculture," Robert R. Wilson, Federal Energy Office, Washington, D. C.

Paper: "Energy Research Priorities for U. S. Agriculture," Walter R. Butcher and Norman K. Whittlesey, Washington State University

Topic: The Role of Cooperatives in Future Agriculture

Chairman: Marshall R. Godwin, USDA-FCS, Washington, D. C.

Paper: "Cooperative Strategies in Imperfectly Competitive Market Structures," Ronald D. Knutson, USDA-FCS, Washington, D.C.

Paper: "The Present and Future Legal and Political Climate of Farmer Cooperatives," Loyd McCormick, with McCutchen, Doyle, Brown and Enersen, San Francisco

Paper: "Cooperatives as a Means of Solving the Problems of Low-Income Rural People," T. T. Williams, Southern University

Topic: Forest Economics

Chairmen: Emmett F. Thompson and John E. Waldrop, Jr., Mississippi State University

Paper: "Economic Tradeoffs in Multiple Use Management of Forest Land," Marion Clawson, Resources for the Future, Inc., Washington, D. C.

Paper: "Timber Supply: Goals, Prospects and Problems," William A. Duerr, Virginia Polytechnic Institute and State University

Topic: Financing Public Services in Rural Areas

Chairman: Fred H. Tyner, Mississippi State University

Paper: "Planning and Managing Public Service Delivery Systems in Rural Areas: A Conceptual Framework," Lonnie L. Jones, Texas A & M University, and Paul H. Gessaman, University of Nebraska

Paper: "Local Funding of Rural Public Services," Wilbur R. Maki, University of Minnesota

Paper: "Nonlocal Funding of Rural Public Services," John S. Bottum, USDA-FES, Washington, D. C.

Topic: Measuring the Reality of Modern Agriculture: New Concepts and Statistical Systems

Chairman: James T. Bonnen, Michigan State University

Paper: "Concepts of the Agricultural Economy," Thomas A. Carlin and Charles R. Handy, USDA-ERS, Washington, D. C.

Paper: "Monitoring the Agricultural Economy: Strains on the Data System," Eldon E. Weeks, Gerald E. Schluter, and Leland W. Southard, USDA-ERS, Washington, D. C.

Paper: "Public Policy Demands and Statistical Measures of Agriculture," Leo V. Mayer, Council of Economic Advisors, Washington, D. C., and J. Dawson Ahalt, USDA-ERS, Washington, D. C.

Monday Evening, August 19

Industry and International Dinner: The Role of Public and Private Sectors in East-West Trade

Current Agricultural Policy Issues: Panel

Tuesday Morning, August 20

Annual Business Meeting

General Session

Fellows Address: "Agriculture's Capacity to Produce in the Future (A World Viewpoint with Emphasis on the U. S.)," George E. Brandow, Pennsylvania State University

Invited Address: "Conflicts—U. S. Agriculture in an Urban Society," T. W. Schultz, The University of Chicago

Tuesday Afternoon, August 20

Topic: Economic Research and Education for Commercial Agriculture

Chairman: R. James Hildreth, Farm Foundation, Chicago, Illinois

Paper: "Perspective on Research and Education for Commercial Agriculture," Robert W. Long, Assistant Secretary, USDA, Washington, D. C.

Paper: "Economic Research and Education Issues for Commercial Agriculture," Richard L. Kohls, Purdue University

Topic: Subsector Analysis—An Appraisal

Chairman: George D. Irwin, USDA-ERS, North Carolina State University

Paper: "Subsector as a Conceptual Framework for Guiding and Conducting Research," Ben C. French, University of California, Davis

Paper: "Hog-Pork Subsector Study in Review: Research and Administrative Experience," Wilfred V. Candler, Canada Department of Agriculture, and Alden C. Manchester, USDA-ERS, Washington, D. C.

Topic: Marine Economics: Production and Marketing of Seafood Products

Chairman: Fred J. Prochaska, University of Florida

Paper: "Food from the Sea: An Economic Perspective of the Seafood Market," Richard J. Marasco, University of Maryland

Paper: "The Economist and the Seafood Producer," Frederick J. Smith, Oregon State University

Topic: Agricultural Finance and Economic Policy

Chairman: Edwin C. Price, Jr., Board of Governors of the Federal Reserve System, Washington, D. C.

Paper: "The Impact of Monetary Actions on Farm Income and Finance," Darryl R. Francis, Federal Reserve Bank, St. Louis, Missouri

Paper: "Farm Finance and Economic Policy: Gaps in Knowledge," John R. Brake, Michigan State University

Paper: "Sources and Uses of Funds in Agriculture," Olin B. Quinn, Federal Land Bank, New Orleans, Louisiana

Topic: Agricultural and Rural Labor Resources

Chairman: Robert D. Emerson, University of Florida

Paper: "A Model of an Agricultural Labor Union," George W. Ladd, Iowa State University

Paper: "Work Behavior of Rural Non-Farm Wage Earners," D. Lee Bawden, University of Wisconsin

Paper: "Economic Implications of Unemployment Insurance for Agriculture," Stanley K. Seaver, University of Connecticut, and James S. Holt, Pennsylvania State University

TUESDAY EVENING, AUGUST 20

Invited Address: "Food, Agriculture and Rural Welfare: Domestic Policies in an Uncertain World," Willard W. Cochrane, University of Minnesota

Awards Program

Chairman: Bernard F. Stanton, Cornell University

WEDNESDAY MORNING, AUGUST 21

General Session

Invited Address: "Domestic Food Costs," Leo V. Blakley, Oklahoma State University

Invited Address: "Some Economic Aspects of Agricultural Regulation," James P. Houck, Jr., University of Minnesota

Topic: National Population Distribution Policies and Programs

Chairman: J. Dean Jansma, Pennsylvania State University

Paper: "Population Distribution and Economic Growth: Policy Options and Research Implications," W. Burl Back, Office of the Secretary, USDA, Washington, D. C.

Paper: "Public Goods Delivery Systems: Problems and Policies in Rural Areas," Paul W. Barkley, Washington State University

Paper: "Land Use Planning Policy with Implications for Commercial Agriculture," Lawrence W. Libby, Michigan State University (currently on leave with Resources for the Future, Inc.)

Topic: Interfacing the Classroom and the World of Work

Chairman: Wayne D. Purcell, Oklahoma State University

Paper: "The Internship: A Necessary Condition for Effective Undergraduate Instruction," Milton M. Snodgrass, New Mexico State University

Paper: "Alternatives to the Internship: Bringing the Real World to the Classroom," Charles E. French, Purdue University

Topic: Training in International Agricultural Development: The Role of the American Agricultural Economics Profession

Chairman: Abraham M. Weisblat, Agricultural Development Council

Paper: "Objectives of International Training," D. Gale Johnson, University of Chicago

Paper: "Institutions and Methods in International Training," Darrell F. Fienup, Michigan State University and Ford Foundation

Paper: "Ways to Improve International Training," Lyle P. Schertz, USDA-ERS, Washington, D. C., and Walter P. Falcon, Stanford University

CHANGE OF EDITORSHIP OF AJAE

Starting with the February 1975 issue, the editorial staff of the *American Journal of Agricultural Economics* will include:

Editor—William G. Tomek
Associate Editors—Richard N. Boisvert
Donald K. Freebairn

New submissions of manuscripts after July 1 should be sent to W. G. Tomek, Department of Agricultural Economics, Warren Hall, Cornell University, Ithaca, New York 14850. An announcement about the Book Review Editor will be made in the August issue.

1974
NOMINEES
FOR OFFICES OF THE AAEA

PRESIDENT

James T. Bonnen, Michigan State University
Ben C. French, University of California, Davis

DIRECTORS

I

G. Edward Schuh, Purdue University
and
Bernard F. Stanton, Cornell University

II

Fred A. Mangum, North Carolina State University
and
V. James Rhodes, University of Missouri-Columbia

INTERNATIONAL ASSOCIATION OF AGRICULTURAL ECONOMISTS, U. S. COUNCIL

The recent election held by United States members of the International Association of Agricultural Economists resulted in the choice of Lyle P. Schertz and Norman Collins. The membership of the U. S. Council for the 1973–76 period is M. L. Upchurch, Max Myers, Lyle P. Schertz, and Norman Collins. In accordance with usual procedures, the members of the Council will elect their chairman.

FULBRIGHT-HAYS AWARDS

U. S. citizens who have a doctorate or college teaching experience are invited to apply for the more than 550 university lecturing and advanced research awards during 1975–76 in over 75 countries under the senior Fulbright-Hays program, the Council for International Exchange of Scholars (formerly the Committee on International Exchange of Persons). The registration form is available upon request from the Senior Fulbright-Hays Program, 2101 Constitution Avenue, N.W., Washington, D. C. 20418. Deadline for applying is July 1, 1974. Also available upon request to the Council is a directory of senior Fulbright-Hays foreign scholars who are in the U. S. this academic year.

AAEA COMMITTEE STRUCTURE, 1973–74

AWARDS COMMITTEE

B. F. Stanton, Chairman, Cornell, 1972

Distinguished Undergraduate Teacher Award

John W. Goodwin, Chairman, Oklahoma State, 1971
Hoy F. Carman, California-Davis, 1973
W. David Downey, Purdue, 1972
Thomas L. Frey, Nebraska, 1971
Brad Gungoll, Oklahoma State, 1973 (student)
Russell F. McDonald, Texas A & M, 1972
Robert O. Sinclair, Vermont, 1973
Robert G. F. Spitze, Illinois, 1973

Distinguished Extension Program and Publications Awards

Jean B. Wyckoff, Chairman, Oregon State, 1970
William M. Carroll, Pennsylvania State, 1971
Martin K. Christiansen, Minnesota, 1971
Duane E. Erickson, Illinois, 1971
John G. Holt, Florida, 1973
H. C. Lampe, Rhode Island, 1973
William V. Neely, Extension Service, USDA, 1973
Gordon D. Rose, South Dakota State, 1972

Published Research Awards

Gene L. Swackhammer, Chairman, FCA, Washington, D. C., 1972

Discovery

William D. Dobson, Wisconsin, 1973
Burton L. French, ERS, USDA, 1973
Stanley R. Johnson, Missouri, 1973
Donald S. Moore, Texas A & M, 1971
Brian B. Perkins, Canada Dept. of Agriculture, 1971
Schlomo Reutlinger, IBRD, Washington, D. C., 1972
Andrew Vanvig, Wyoming, 1973
Richard G. Walsh, Colorado State, 1972

Communication

Jack H. Armstrong, FCS, USDA, 1973
George L. Capel, North Carolina State, 1972
Roger W. Fox, Arizona, 1973
Dennis R. Henderson, Ohio State, 1973
Ralph G. Kline, Virginia Polytechnic, 1972
Wayne D. Rasmussen, ERS, USDA, 1973
Mary C. Templeton, West Virginia University, 1973

Master's Thesis Awards

Joseph Havlicek, Jr., Chairman, Purdue, 1973
Roice H. Anderson, Utah State, 1973
Garnett L. Bradford, Kentucky, 1973
David W. Brown, Tennessee, 1973
Johannes Delphendahl, Maine, 1972
C. Dirck Ditwiller, Washington State, 1973
Roger G. Johnson, North Dakota State, 1972
Jerry M. Law, Louisiana State, 1973
Tsoung-Chao Lee, Connecticut, 1971
Douglas E. Morris, New Hampshire, 1972
Robert Raunikar, Georgia, 1973
John R. Schaub, ERS, USDA, 1973
Edward H. Ward, Montana State, 1971

Doctoral Dissertation Awards

Marvin L. Hayenga, Chairman, Michigan State, 1971
David M. Bell, ERS, USDA, 1973
Rachel Dardis, Maryland, 1972
Buddy L. Dillman, Clemson, 1973
Kenneth D. Duft, Washington State, 1972
Bernard L. Erven, Ohio State, 1972
Charles R. Handy, ERS, USDA, 1973
Douglas D. Hedley, Canada Dept. of Agriculture, 1973
R. M. A. Lyons, Food Prices Review Board, Ottawa, 1973
William C. Merrill, Iowa State, 1973
Earl J. Partenheimer, Pennsylvania State, 1973
L. Orlo Sorenson, Kansas State, 1973
Forrest E. Walters, Colorado State, 1973

Publications of Enduring Quality

Earl R. Swanson, Chairman, Illinois, 1973 (4 years)
D. Lee Bawden, Wisconsin, 1973 (2 years)
Vernon R. Eidman, Oklahoma State, 1973 (3 years)
Robert M. Finley, Missouri, 1973 (1 year)
Robert S. Firch, Arizona, 1973 (2 years)
Marshall R. Godwin, FCS, USDA, 1973 (1 year)
Thomas F. Hady, RDS, USDA, 1973 (4 years)
Allen B. Paul, ERS, USDA, 1973 (3 years)
Ronald A. Schrimper, North Carolina State, 1973 (4 years)

PROFESSIONAL ACTIVITIES

Luther T. Wallace, Chairman, California, 1971
Charles L. Beer, Extension Service, USDA, 1973
Raymond O. P. Farrish, Connecticut, 1970
R. James Hildreth, Farm Foundation, 1971
Linley E. Juers, ERS, USDA, 1971
James S. Plaxico, Oklahoma State, 1970
Wayne D. Purcell, Oklahoma State, 1973
Lyle P. Schertz, ERS, USDA, 1970

EXTENSION AFFAIRS

Charles L. Beer, Chairman, Extension Service, USDA, 1973
William M. Carroll, Pennsylvania State, 1972
George L. Casler, Cornell, 1972
Charles D. Covey, Florida, 1973
Kenneth D. Duft, Washington State, 1971
W. Neill Schaller, Farm Foundation, 1970

INDUSTRY ADVISORY

Raymond E. Seltzer, Chairman, Development Planning & Research Associates, Inc., 1970
Ronald O. Aines, International Harvester Company, 1973
W. Bernard Lester, Florida Department of Citrus, Gainesville, 1973
Gerald G. Quackenbush, American Dairy Association, 1970
Ted Rice, Continental Grain, 1973
Bernard L. Sanders, Farmland Industries, 1973
Gene D. Sullivan, Federal Reserve Bank, Atlanta, 1973

INTERNATIONAL

Lyle P. Schertz, Chairman, ERS, USDA, 1970
Harold F. Breimyer, Missouri-Columbia, 1973
Emery N. Castle, Oregon State, 1973
Norman R. Collins, Ford Foundation, 1972
Walter P. Falcon, Stanford, 1973
J. Price Gittinger, IBRD, Washington, D. C., 1973
Clive R. Harston, Texas A & M, 1972
Earl O. Heady, Iowa State, 1970
James P. Houck, Jr., Minnesota, 1973
James S. Plaxico, Oklahoma State, 1973
Wayne W. Sharp, FAS, USDA, 1973
Orlin J. Scoville, Kansas State, 1972
Abraham M. Weisblat, Agricultural Development Council, 1973

AUDIT

James E. Criswell, Chairman, Kentucky, 1970
Fred E. Justus, Jr., Kentucky, 1970

BIBLIOGRAPHICAL

Lee M. Day, Chairman, Pennsylvania State, 1970
William Darcovich, Canada Dept. of Agriculture, 1970
J. Edwin Faris, Washington State, 1970
Allen S. Johnson, ERS, USDA, 1973
Richard C. McArdle, ERS, USDA, 1973
Ivan W. Schmedemann, Texas A & M, 1972
John T. Scott, Illinois, 1972

ECONOMIC STATISTICS

James T. Bonnen, Chairman, Michigan State, 1970
R. James Hildreth, Farm Foundation, 1969
George G. Judge, Illinois, 1969
George S. Tolley, Chicago, 1969
Harry C. Trelogan, SRS, USDA, 1970
Quentin M. West, ERS, USDA, 1972

Employment Services

Loys L. Mather, Chairman, Kentucky, 1968
Joseph Ackerman, Ford Foundation, 1973
David H. Boyne, Ohio State, 1969
Carleton C. Dennis, Agway, Inc., 1972
Stephen B. Harsh, Michigan State, 1973
Dale E. Hathaway, Michigan State, 1971
Melvin R. Janssen, EDD, ERS, USDA, 1969
Howard F. Robinson, North Carolina A & T, 1972

Fellows Election

Glenn L. Johnson, Jr., Chairman, Michigan State, 1970
Karl A. Fox, California, 1972
Nathan M. Koffsky, Chevy Chase, Maryland, 1969
Don Paarlberg, USDA, 1971
Lauren K. Soth, Des Moines Register and Tribune, 1973

Investment

John C. Redman, Chairman, Kentucky, 1970
Dale E. Butz, Illinois Agricultural Association, 1970

Membership

John E. Lee, Jr., Chairman, ERS, USDA, 1972
Kenneth D. McIntosh, West Virginia University, 1973
Ted R. Nelson, Oklahoma State, 1973
John C. Redman, Kentucky, 1970
Herbert H. Stoevener, Oregon State, 1973

Nominating

Emery N. Castle, Chairman, Oregon State, 1973
Charles L. Beer, USDA Extension Service, 1973
Dale E. Butz, Illinois Agricultural Association, 1973
George E. Frich, New Hampshire, 1973
James R. Gray, New Mexico State, 1973
James R. Martin, Texas A & M, 1973
John B. Sjo, Kansas State, 1973
Glen V. Vollmar, Nebraska, 1973

Postwar Literature Review

Lee R. Martin, Chairman, Minnesota, 1967
John P. Doll, Missouri-Columbia, 1968
Peter G. Helmberger, Wisconsin, 1969
Glenn L. Johnson, Michigan State, 1967
Maurice M. Kelso, Tucson, Arizona, 1967
J. Patrick Madden, Pennsylvania State, 1969
Edward W. Tyrchniewicz, Manitoba, 1969
M. Louis Upchurch, Florida, 1967

Resident Instruction

Wayne D. Purcell, Chairman, Oklahoma State, 1973 (2 years)
Charles E. Erickson, Cargill, Inc., 1973 (2 years)
Lonnie L. Jones, Texas A & M, 1973 (3 years)
James G. Kendrick, Nebraska, 1973 (3 years)
Lester V. Manderscheid, Michigan State, 1973 (1 year)
John W. Nixon, Georgia, 1973 (1 year)

Institutional Membership

Dale E. Butz, Chairman, Illinois Agricultural Association, 1973
S. Kent Christensen, National Assn. of Food Chains, 1965
Charles E. Erickson, Cargill, Inc., 1973
Dean E. McKee, Deere & Company, 1973
Joseph H. Marshall, Cotton Producers Assn., 1970
Charles R. Sayre, Staple Cotton Cooperative Assn., 1965
Roy G. Stout, Coca-Cola, Atlanta, 1970

AAEA Board Member Liaison

Howard F. Robinson, North Carolina A & T, 1973

Tellers

A. Frank Bordeaux, Jr., Chairman, Kentucky, 1970
Harry H. Hall, Kentucky, 1973

Visiting Professor

R. James Hildreth, Chairman, Farm Foundation, 1969
William Herr, Southern Illinois, 1973
T. T. Williams, Southern University, 1973
Kenneth E. Wing, Maine, 1973

AAEA Representative to the Agricultural Development Council, Research and Training Network Program (ADC/RTN)

Lyle P. Schertz, ERS, USDA

AAEA Representative to the American Society of Agronomy
(Mutual appointment with the American Society of Agronomy)

C. Ray Hoglund, Michigan State

AAEA Representative to the Council for Agricultural Science and Technology

George E. Brandow, Pennsylvania State

AAEA Representative to the National Bureau of Economic Research

Harold G. Halcrow, Illinois

AAEA Representative to the National Research Council

George E. Brandow, Pennsylvania State

AAEA Representative to the Bureau of Census Advisory Committee on Agricultural Statistics

James T. Bonnen, Michigan State

ASA-AAEA Joint Advisory Committee on Agricultural Statistics

James T. Bonnen, Chairman, Michigan State
George C. Judge, Illinois
Dean E. McKee, Deere & Company

U.S. Council of the International Association of Agricultural Economists

M. Louis Upchurch, Chairman, Florida
Norman R. Collins, Ford Foundation
Maxwell S. Myers, South Dakota State
Lyle P. Schertz, ERS, USDA

AAEA Representative to Allied Social Science Associations Winter Meetings

Werner Kiene, Ford Foundation

AJAE Evaluation

Stephen M. Smith, Chairman, Wisconsin
Gordon A. King, California-Davis
William C. Motes, EDD, ERS, USDA
Claud L. Scroggs, Southern States Cooperative, Inc.
Stanley K. Seaver, Connecticut
Herbert H. Stoevener, Oregon State
Earl R. Swanson, Illinois
George S. Tolley, University of Chicago
Henry A. Wadsworth, Purdue

ADDENDUM

Editor's Note: Reports of the Ad Hoc Special Committee on Student Affairs and Undergraduate Education and the Awards Committee were inadvertently omitted from the December 1973 issue of the *AJAE*. Reports of the AAEA Representative to the National Bureau of Economic Research and the Ad Hoc Committee on Balloting and Mailing Procedures were received too late to appear in the December 1973 issue. These four reports are printed below. Committee reports should be given directly to the Editor at the annual August meeting to insure inclusion in the December issue.

REPORT OF THE SPECIAL COMMITTEE ON STUDENT AFFAIRS AND UNDERGRADUATE EDUCATION

During the 1972 Gainesville Meetings, the Board of Directors of AAEA adopted a special resolution establishing ". . . a special committee . . . to evaluate student activities of the Association; that this committee be concerned not only with the existin student affairs activities but also with potential pr grams and with the role of undergraduate profe sional education. . . ." To carry out this assignmen the committee chairman asked Dr. John Sjo to pr pare a statement outlining the background and d velopment of student activities of the Associatio as they now exist and as they might be. In additio Dr. Don Epp was asked to conduct a survey of unit teaching agricultural economics as well as unde graduate students in Agricultural Economics to d termine why they have or have not participated i AAEA activities and to solicit suggestions for futur programs. The Sjo and Epp contributions provid extremely valuable background material to this r port. (The Sjo contribution is published in the Sho Articles/Notes section of this issue. The Epp contr bution can be obtained by writing D. J. Epp, Weave Building, The Pennsylvania State University, Un versity Park, Pennsylvania 16802.)

After extensive correspondence reacting to the Sj paper and providing other input, as well as numerou phone calls, the committee met in Kansas City, Missouri, July 16–18, 1973, to discuss the issues involved and to draft a document to be presented to the Board of Directors. Each committee member has commented on this draft which is considered to constitute the final report of the committee.

Basic Considerations

In undertaking its assignment, the special committee interpreted the charge to be a broad one. Specifically, we undertook to consider the potential role of AAEA as it might relate to the total program of resident instruction in agricultural economics including graduate instruction and also including possible student activities in association with AAEA meetings.

It is the view of the special committee that

(1) Resident instruction, particularly at the undergraduate level, will occupy an increasingly important position in agricultural economics departments in the future. There are several reasons to expect greater professional interest and involvement in undergraduate instruction. These include increasing accountability in higher education and the escalating need for economic literacy in the food sector. A more detailed outline of this rationale can be obtained from this committee's chairman.

(2) In the past AAEA has not been teaching or teacher oriented. Yet there is an important and essential role for the Association in relation to teaching programs.

It is clear that each unit involved in teaching agricultural economics serves diverse clientele groups including students enrolled in service courses, students majoring in agricultural economics with an interest in agriculture and agriculturally related business careers, and students enrolled in agricultural economics as pre-professional preparation. At the same time, the mix of clientele served by different units teaching agricultural economics is vastly different. Further, the environment in which the various units teaching agricultural economics operate is changing at a phenomenal rate.

A review of the Sjo and Epp contributions, as well as the observations and experiences of the committee, clearly suggest that the Association can more effectively contribute to the improvement of resident instruction through teacher-oriented programs than through student-oriented programs. This is necessarily the case because a very small proportion of students participate in Association activities and there is little feedback to fellow students. Thus, there is essentially no continuity nor multiplier effect within the student group. On the other hand, teacher centered programs providing stimulation, ideas, and professional exchanges for teachers offer a potential for carryback to units teaching agricultural economics as well as carryover into the future. Teacher oriented activities provide a base on which to build. Thus it is the consensus of the committee that if it is the objective of the Association to provide a more meaningful educational experience for students, the Association can best achieve this objective by supporting teacher-centered activities.

Specific Recommendations

As the Sjo paper indicates, since its beginning the Association has been concerned about and uncomfortable with its programs relating to instruction. The special committee feels that the Association must devote more attention to resident instruction aspects of the profession. To direct such attention, the committee offers the following action oriented specific recommendations:

I. *The special committee recommends that the Executive Committee of AAEA establish a resident instruction committee as a standing committee to replace both the student activities committee and the education committee.* The Resident Instruction Committee should consist of six members on staggered terms and initially composed of two members appointed for one year, two for two years, and two for three years. Subsequent appointments would be for three-year terms. The president of the Association should appoint the committee and designate a chairman of the committee. The chairman of the committee in turn may appoint subcommittees to carry out specified tasks within the charge of the committee. The subcommittees may include members of the resident instruction committee, other members of the Association, students, and others as needed. Subcommittee appointment would be subject to the approval of the president of AAEA.

The specific duties of the committee on resident instruction would include:

(1) Advising the Association president regarding program sessions of the annual meetings relating to resident instruction.

(2) Evaluating alternatives regarding student participation or nonparticipation in the affairs of the Association and making specific recommendations to the Board of Directors.

(3) Considering the role or roles of the Association in the preparation of teaching aids such as CAI programs, visual aids, and programmed instruction aids. The committee would then make specific recommendation to the Board of Directors and membership relative to the relevance, development, availability, and dissemination of such aids.

(4) Making recommendations to the Board relative to the possible establishment and maintenance of a roster of Association members who might be available to serve, upon invitation of the department concerned, as members of resident instruction consulting teams in agricultural economics.

(5) Monitoring emerging trends, problems, and needs relating to resident instruction, including curricula, courses, job markets, and orientation and to advise the Board and membership through appropriate channels.

(6) Relating to and advising the *Journal* editor relative to *Journal* content in the area of resident instruction.

(7) Evaluating the feasibility of Association sponsorship of regional teaching committees, perhaps with Farm Foundation or other financial support of regional planning committees in each region. These regions may or may not be the same as Experiment Station regions, but institutions teaching agricultural economics, both Land Grant and non-Land Grant, should be invited to participate.

II. *The special committee strongly recommends that the Association provide improved channels of communications among members relative to problems and potentials in resident instruction.* Two major communication channels exist among members of the AAEA—the Annual Meetings and the *Journal.* The content of these two channels conveys to members and potential members, both graduate students and professionals, the activities considered important by the Association. If the Association values instructional activities and wants to attract and serve agricultural economists interested in teaching, its best strategy is to integrate fully materials relating to teaching into the two major channels of communication. To do otherwise, such as restricting these materials to special meetings or workshops or a separate *Journal,* is to imply separation and, more than likely, a lower status. Thus, it is recommended that:

(1) A session or sessions of the annual meetings be organized around topics relating to resident instruction. The proposed standing committee on resident instruction should be consulted for guidance regarding the most important topics for such meetings.

(2) The *Journal* editor be encouraged to exert maximum effort to incorporate increased attention to teaching activities in the *Journal.* Special actions to be taken by the editor should include (a) initiation of the Educator's Corner section to present short items related to both resident and extension instructional activities. Such a section might be considered temporary until such time as the precedent for regular inclusion of teaching material is well established. (b) Request department chairmen or other administrators specifically to encourage and stimulate preparation of materials relating to teaching for inclusion as regular articles, short articles, or in the Educator's Corner. (c) Revise the request to News Notes correspondents to include as organizational news items, material related to curricula revisions, or new courses that clearly break with tradition. (d) Request or commission specific articles where the editor or the resident instruction committee has knowledge of teaching materials potentially worthy of publication.

III. *The special committee recommends that student activities of AAEA (debates, public speaking, and essays) continue through the 1974 meetings but that these activities not be continued after 1974 unless the resident instruction committee determines that there is an expressed need and well defined role of such activities in the future.* The number of schools participating and the number of students involved in the various student activities are limited because of the faculty commitment required as well as the funding problem, including opportunity costs faced by both students and their sponsors. Further, the student activities as currently constituted are essentially separated from other AAEA activities, which limits the opportunities that students attending have to interact with Association members. For those professionals advising student contestants, there is little opportunity to participate in non-student related phases of the Association meetings. The *Journal* and the 1974 meetings should provide a forum for open discussion of this and related issues.

IV. *The special committee recommends that the resident instruction committee assume the duties of the student affairs committee as currently outlined in the By-Laws of the Association.* Such a change would involve substituting the words "resident instruction committee" for "student affairs committee" in the By-Laws as follows: Sec. 1, p. 2, line 1; Sec. 2, line 6, line 8, line 10, line 12, and line 13; Sec. 2, p. 3, line 1; Sec. 3, line 13; Sec. 4, p. 4, line 6, and line 8; and Sec. 5, lines 1 and 2.

V. *If Association Awards programs are to be continued, the teaching awards should be continued and consideration should be given to establishing an award for the development of teaching materials.* Further consideration should be given to *Journal* listing of awards presented on the various campuses in recognition of superior teaching.

Respectfully submitted,
JOHN SJO
DONALD EPP
JAMES KENDRICK
LESTER MANDERSCHEID
WALTER WILLS
JAMES PLAXICO, *Chairman*

REPORT OF THE AWARDS COMMITTEE

The committee under the leadership of C. B. Baker continued its evaluation and proposals for revision of the Association's awards program. The Chairmen of each of the sub-committees met with Baker and President Castle in Chicago in December 1972 and prepared a final report presented to the Executive Board at its meeting in Toronto [*Am. J. Agr. Econ.* 55:338–340, May 1973]. The report was accepted in principle after discussion with the proviso that the final wording of specific announcements for the new awards programs be submitted for review by the Board at its meeting in August 1973. Each of the sub-committee chairmen prepared the necessary copy for review, and after revision it was approved for distribution to the membership. Multilithed copies were sent to major colleges, universities, agencies, and organizations in November 1973.

Award winners were selected in each of the categories by separate subcommittees during the four spring months of 1973. Economists from nearly all of the universities and major organizations represented in the Association participated in the selection process. It is a substantial activity involving many people for which the Association and the profession expresses thanks for the time and effort involved.

The Awards Committee with the approval of the President and Executive Board published an awards program listing all the nominations made by departments or individuals in each of the awards categories. This program was distributed at the time individual awards were presented at Edmonton, Alberta. There were 12 nominations for the extension program award and 13 for the extension publication award. Distinguished undergraduate teacher awards were selected from among six nominees with less than 10 years of experience and nine nominees with more than 10 years of experience. Twenty-three M.S. theses were reviewed and 32 Ph.D. theses by the two thesis award committees. A total of 25 publications were systematically reviewed in the published research category.

A nominee on behalf of the AAEA for the Browning award was selected and appropriate documentation prepared in February 1973. It is proposed that the Executive Board establish a special committee to select and present the Association's nominee for this award in succeeding years so that the best possible candidate is properly supported by necessary evidence and materials.

Respectfully submitted,
B. F. STANTON, *General Chairman*

REPORT OF THE AAEA REPRESENTATIVE TO THE NATIONAL BUREAU OF ECONOMIC RESEARCH

Staff Research Programs

During 1973 the staff of the National Bureau carried on more than a hundred individual research projects that were classified in the following general categories: (1) Economic and social performance, including productivity, employment, and price levels; measurement and analysis of national income, nonmarket activities, and development of microdata bases; business cycles, the velocity of money, cyclical indicators, and short-term forecasting; modeling the consequences of alternative fiscal policies, revenue sharing, and grant-in-aid programs; (2) Urban and regional studies, including models of urban change, housing stocks and markets, industry, and residential location decisions; (3) Human behavior and social institutions, including education and information and distribution of income; legal, judicial, and administrative procedures, law enforcement and deterrent effects on crime; economics of health and health-care programs; population and family economics; (4) Financial institutions and processes, including inflation and financial markets, policies of major financial institutions, household savings, and individual investor portfolios; (5) Industrial organization and processes, diversification, mergers, rates of return on investment outlays, and effects of advertising; (6) International economic relations, role of the dollar, prices in international trade, and effects of direct investment on recipient countries; (7) Research on computer-based quantitative methods, data banks, and statistical methodology. Summaries of the respective research projects underway are given in the National Bureau's 53rd Annual Report, September 1973, copies of which are available from the National Bureau upon request.

Seminars, Conferences and Workshops

The National Bureau staff conducted a weekly seminar program at the New York office. The program provides an opportunity to discuss topics of current research interest proposed by members of the staff. Guest lectures by scholars from various universities and research institutions in the U. S. and abroad supplement the program. Visitors from other institutions and business organizations are welcome to attend this on-going program of seminars.

The Conference on Research in Income and Wealth met on November 30–December 1, 1973, in Washington, D. C. under the Chairmanship of Nestor E. Terleckyj, to discuss Household Production and Consumption. Future conferences include Distribution of Economic Well-Being, University of Michigan, May 1974, F. Thomas Juster, Chairman; Price Behavior, Fall of 1974, Joel Popkin, Chairman; and Economics of Urban Spatial Structure, Spring of 1975, Gregory K. Ingram, Chairman.

The last conference of the Universities-National Bureau Committee for Economic Research was on Economics of the Environment, November 10–11, 1972, at the University of Chicago. A conference on the Role of Health Insurance in the Health Services Sector is scheduled for May 31–June 1, 1974, at the University of Rochester, Richard N. Rossett, Chairman. Another is being planned on the Economic Analysis of Political Behavior, under the Chairmanship of Melvin W. Reder.

The Conference on the Computer in Economic and Social Research held a conference on Research and the 1970 Public Use Sample, in Atlanta, Georgia, on March 23–24, 1973, with Richard and Cynthia Taeuber as Chairmen; and another conference on Consumer Prices and Expenditures in Williamsburg, Virginia, on May 3–4, with Joel Popkin, Robert Ferber, and Malcolm Cohen as Chairmen. Workshops also sponsored by this Conference included: Matching and Merging of Data Sets, Benjamin Okner, Chairman, May 4–5, 1973, Williamsburg, Virginia; Stochastic Control and Economic Systems, Gregory Chow, Chairman, June 7–9, University of

Chicago; and Macroeconomic Simulation Teaching Games, F. T. Dolbear, Chairman, October 26, National Bureau, New York City.

The Latin American Computer Workshop met in Caracas, Venezuela, February 28–March 2, 1973. The program, organized by Saul Trejo, was on macroeconomic policy models. A second workshop of this series, organized by Affonso Pastore, met in Sao Paulo, Brazil, on July 23–25 and dealt with patterns of employment in Latin America. A conference sponsored jointly by the NBER and the International Association for Research in Income and Wealth is scheduled to be held in Rio de Janeiro on January 9–12, 1974, and will deal with national and regional accounts and microdata for economic and social research.

The Conference on Econometrics and Mathematical Economics operated in 1973 through 13 on-going working groups, which met at various host universities, under the leadership of a member of the local faculty. The members of each group are drawn from scholars throughout the country who are experts in particular fields. Typically each working group met twice during the year for seminars focused on specific areas such as general equilibrium models under Kenneth J. Arrow, analysis of panel microdata under James N. Morgan, and Bayesian Inference in econometrics under Arnold Zellner.

Publications

Seven reports were published in 1973, including two volumes of conference proceedings and five staff studies comprised of four books and one occasional paper. Five other conference volumes and seven books were in press in late November. A list of Bureau publications is available on request. Four numbers of the National Bureau's journal, *Annals of Economics and Social Measurement,* were issued in 1937, and in addition to the *Annual Report,* three issues of the newsletter, National Bureau Report, were distributed to contributors, subscribers and others interested in current Bureau affairs. Some decentralization of Bureau activities is now achieved by branch offices in Cambridge, Massachusetts, and New Haven, Connecticut, and a new office to be opened in 1974 at Stanford, California. As is consistent with the tradition of the National Bureau, research in growth, inflation, and the business cycle uses a good portion of Bureau resources. At the same time new emphasis is being placed on structural and sectional analyses, and computer-based quantitative analysis.

HAROLD G. HALCROW

REPORT OF AD HOC COMMITTEE ON BALLOTING AND MAILING PROCEDURES

At the annual meetings of the Association in August 1973 some expressions of dissatisfaction with balloting and mailing procedures were made to officers of the Association. Subsequently, President Tefertiller appointed an ad hoc committee consisting of W. B. Sundquist and Lee M. Day to review procedures in the Office of the Secretary-Treasurer with special emphasis on balloting procedures. The committee visited the University of Kentucky in November 1973 where we conferred with John Redman, Secretary-Treasurer; the teller committee; the stenographic staff that handles Association business; and postal employees.

Findings

Although the paid-up membership during the year usually runs between 4,000 and 5,000 members, less than 2,100 members had actually paid their dues and were, therefore, eligible to vote as of April 1 as required by the by-laws.

To the best of our ability to determine, it appears that the postage charges for ballot mailing in 1973 corresponded very closely to the number of eligible voters on record as of April 1, 1973. Any verification of the number of ballots going out under permit mailing is subject to some discrepancy because of the gross procedures for determining the number of pieces of mail at the university post office. There is no actual count by the post office of the number of pieces of mail. The count is determined by weighing the total mailing and dividing this weight by an average weight per envelope, which in turn is based on the weighing of a similar sample of envelopes. Postage charges paid for ballot mailing in 1973 closely approximate the postage charge estimated by multiplying the number of eligible voters by the unit postal charges for permit mailings. Moreover, we found the procedures being used in the office of the Secretary-Treasurer to be both effective and efficient. The filing system for keeping the set of mailing addresses up-to-date and for determining eligible voters appeared as efficient as possible, and each member now has a file number. Incoming mail to the Secretary-Treasurer's office is normally logged in and handled on a daily basis and not permitted to pile up. Date for payment of individual members' dues is also logged in systematically and promptly. In discussion with the tellers committee, we found them to be desirous of having a rather specific set of operating instructions from the Executive Board of the Association. This appears to be a warranted request given some of the subjective decisions they must currently make in determining validity of ballots.

In summary, we find that much of the dissatisfaction with balloting procedures is probably tied to dues delinquency and use of permit mailing procedures. Also, we believe that the membership is not adequately aware of the extra workload and expense to the Association which is caused by delinquency in dues payment. Thus, any reasonable mechanism to improve the promptness of dues payment should be implemented.

Recommendations

1. That the by-laws of the Association's constitution be amended to eliminate the current requirement for inclusion of a voter's name on the official ballot envelope.
2. That all valid ballots be returned to the Secretary-Treasurer enclosed in an outer envelope which will be marked "Official Ballot Envelope." This marking can be done at the time the envelopes are printed. To be valid, it must be an "official ballot," i.e., not a duplicate or substitute ballot.
3. That prior to mailing of ballot materials to eligible voters, an identifying number be placed on each official ballot envelope which is sent out. This is the outer ballot envelope which currently requires the name of the individual voting. Thus, use of an identifying number will not compromise the secrecy of the ballot.
4. That the February 15 mailing of dues notice include a clear statement saying, "Final notice to maintain eligibility for voting."
5. That the long-standing practice of sending ballots by "permit mail" be discontinued and that the Secretary-Treasurer send all mailings which include ballot materials to eligible members in the U. S., Canada, and Mexico by *first class mail.*
6. That the Secretary-Treasurer continue to send non-ballot bulk mailings to members using the "permit" mailing procedure.
7. That the current practice of sending ballots to foreign members be continued.

The first recommendation requires a modification of the by-laws, all other recommendations relate to operating procedures.

Background and Justification for Recommendations

The basis for making recommendation number one is that an estimated 10 to 20 percent of eligible voters who cast their ballot failed to put their name on the outside envelope as required in the by-laws. Since these individuals appear to be *bona fide* voters and people interested in the activities of the Association, our recommendation is that their vote not be judged invalid merely because their name has not been entered.

The basis for recommendation number two is to avoid the necessity for the tellers committee to make decisions relative to a large number of ballots that currently are submitted in a variety of forms, some of which are difficult to interpret. These include some votes mixed in as write-ins on the form intended for suggestions for next year's officers. Moreover, this will provide a vehicle for implementing recommendation number three.

Recommendation number three is made for the purpose of providing a systematic procedure for documenting the number of ballots mailed out, and providing a basis for checking to see whether or not individual ballots were actually received by the tellers without violating the secrecy of individual ballots. This procedure would also provide a simple checking basis for a variety of other potential mailing problems.

Recommendation number four is made with the hope that this will remind people that in order to be eligible to vote in the upcoming election, they must pay their dues shortly after receiving this mailing. The high incidence of dues payments received from members shortly after they discover they did not receive a ballot due to dues delinquency suggests that significant improvement can be made in the percentage of membership eligible to vote.

The basis for making recommendation number five is the one of having viewed the loose procedures followed by the post office in handling permit mail. The number of pieces of mail is estimated by a gross procedure and mail handling practices can encourage lower percentage deliveries. We feel that the AAEA mailings which include ballots should be sent by first class mail since this would appear to improve the probability of their being received by the addressees. Moreover, using first class mailing also provides another procedure for documenting that the correct number of ballots were mailed by virtue of checking total postage payments against total number of eligible voters.

Recommendation number six is made in order to keep mailing costs within budget constraints. Shifting the single mailing which includes ballots from a permit to first class mail basis would cost the Association in excess of $300. Making other mailing first class would increase costs excessively in our judgment.

Recommendation number seven is made, first, because it appears to be a very economical option. For example, the process permitted 192 foreign mailings to be made at a per unit cost of 21 cents instead of the 63 cents which would have been required to use the same mailout procedure as was used for domestic members only sending the ballots by air mail. Also, there is a very small return of foreign ballots (only 17 of 192 foreign ballots were returned in 1973).

Respectfully submitted,
LEE M. DAY
W. B. SUNDQUIST

News Notes

AGRICULTURE CANADA, ECONOMICS BRANCH

Reassignment: **K. James McKenzie,** formerly project leader with the Research Division, Economics Branch, now Chief of the Farm Management Services Section, Farm and Rural Development Division, Economics Branch.

THE UNIVERSITY OF ALBERTA

Leave: **T. A Petersen,** professor and chairman of the Department of Agricultural Economics and Rural Sociology, on sabbatical in the United States and Western Europe for one year.

THE UNIVERSITY OF ARIZONA

Reassignment: **John C. Day,** associate professor, to Ankara, Turkey, for 12–18 months as Economic Planning Advisor, General Directorate of Planning Research and Coordination, Ministry of Agriculture.

Return: **Roger W. Fox,** associate professor, after three and one-half years at The University of Ceará, Brazil, under an Arizona-Brazil contract.

UNIVERSITY OF CALIFORNIA, BERKELEY

Leave: **Andrew Schmitz,** associate professor, one year sabbatical beginning January 1, 1974, to conduct research at the University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

Resignation: **Jurg Bieri,** assistant professor, to return to Switzerland and private agricultural enterprise.

THE UNIVERSITY OF CHICAGO

Honor: **Theodore W. Schultz** received the National Distinguished Service Award of the American Agricultural Editors' Association on November 27, 1973, for his contribution to agriculture.

COLORADO STATE UNIVERSITY

Leaves: **Huntley H. Biggs,** to Tehran, Iran, to participate for two years as development economist in the formulation of the National Water Plan for Iran; **Rex D. Rehnberg,** to South Korea to serve for six months as a senior adviser in agricultural economics with a Robert R. Nathan Associates consulting team; **Gene C. Wilken,** one-year sabbatical, to study peasant agriculture in Central Mexico.

THE UNIVERSITY OF CONNECTICUT

Appointment: **Bakir Abu Kishk,** assistant professor of resource economics.

Leave: **Robert L. Leonard,** to Washington, D. C. for one year in the Office of the Under Secretary of the Army, Program Planning Group.

Retirement: **Stewart Johnson,** professor of agricultural marketing, after 28 years of service.

CORNELL UNIVERSITY

Return: **Solon L. Barraclough** has returned from several years in Chile and is teaching as adjunct professor during spring 1974.

ECONOMIC RESEARCH SERVICE, USDA

(CED, Commodity Economics Division; FDCD, Foreign Demand and Competition Division; FDD, Foreign Development Division; NEAD, National Economic Analysis Division; NRED, Natural Resource Economics Division.)

Appointments: **Greg Gustafson,** NRED, Washington, D. C.; **Jerome J. Hammond,** Ph.D. Washington State, NEAD; **Jasper Womack,** NRED, Washington, D. C.

Leaves: **Hans G. Hirsch,** FDCD, to the Organisation for Economic Cooperation and Development, Paris, France; **Richard O. Wheeler,** CED, 18 to 24 months at the Center for Food Technology, Sao Paulo, Brazil.

Reassignments: **Clifford Carman,** to Economic Projections and Analytical Systems Program, NEAD; **Austin Fox** to Economic Projections and Analytical Systems Program, NEAD; **John K. Hanes,** CED, to Cooperative State Research Service; **Virden Harrison** to Economic Projections and Analytical Systems Program, NEAD; **Linley E. Juers,** Associate Administrator, ERS, to ERS-Office of the Administrator at Colorado State University, Fort Collins; **Gerald Plato,** Ph.D. Pennsylvania State, to Economic Projections and Analytical Systems Program, NEAD; **Leroy Quance** to Economic Projections and Analytical Systems Program, NEAD.

Resignations: **John R. Brooker,** CED, to The University of Tennessee; **Milton Hallburg,** CED, to Washington, D. C.; **David H. Harrington,** CED, to Indiana; **David B. Narrie,** CED, to Virginia; **James D. Sullivan,** NEAD-Washington, D. C., to Tampa, Florida.

Retirements: **Charles P. Butler,** CED, December 1973; **Anthony G. Mathis,** CED, June 1973.

Return: **Leo R. Gray,** CED, to Albany, California after five months' duty in Senegal, Mali, and Mauritania.

UNIVERSITY OF FLORIDA

Appointments: **Robert O. Coppedge,** formerly at Oregon State, as Extension Economist in rural development; **Richard H. Courtney,** formerly at the University of California at Berkeley, as associate professor; **Gary D. Lynne,** Ph.D. Oregon State, assistant professor in natural resource economics; **Daniel S. Tilley,** formerly at Iowa State, as assistant professor.

UNIVERSITY OF HAWAII

Appointments: **Harold L. Baker,** Director of the Land Study Eureau, University of Hawaii, as professor and agricultural economist; **Salvatore Comitini,** formerly with the Economic Research Center, University of Hawaii, as associate professor and associate agricultural economist; **Walter Miklius,** Director of the Economic Research Center, as professor and agricultural economist; **Bertrand Renaud,** formerly with the Economic Research Center, as associate professor and associate agricultural economist.

Leave: **Chennat Gopalakrishnan,** for six months as Senior Scholar at the East-West Center, Honolulu, Hawaii.

UNIVERSITY OF ILLINOIS

Reassignment: **William N. Thompson,** Director, INTSOY, and Associate Director, International Agricultural Programs.

IOWA STATE UNIVERSITY

Leaves: **Lehman B. Fletcher,** professor, for two years beginning October 9, 1973, to serve as Chief of the Agricultural Economics and Sector Planning Division, Bureau of Technical Assistance, U. S. AID, Washington, D. C.; **Randall A. Hoffmann, Jr.,** temporary associate professor, for two years beginning January 14, 1974, to serve as leader of the farm management and production economics component of the Iowa Universities Peru program in Lima; **Jose T. Mulleady,** visiting assistant professor, for two years beginning February 15, 1974, to serve as farm management economist with the Iowa-Peru program in Lima; **James A. Seagraves,** visiting assistant professor, 18 months beginning October 16, 1973, to serve as water economist with the Iowa-Peru program in Lima.

Reassignment: **Geoffrey S. Shepherd,** professor emeritus, for 18 months in Paraguay as coordinator of a five-man team with the Inter-American Development Bank, which has recently arranged to loan Paraguay 2.4 million dollars for agricultural marketing improvement.

Resignation: **Rudolph K. Schnabel,** instructor in the Cooperative Extension Service, effective November 4, 1973, to join the University of Arizona.

Retirement: **Wallace E. Ogg,** professor in the Cooperative Extension Service, effective December 31, 1973, after serving 38 years with the University.

KANSAS STATE UNIVERSITY

Appointment: **John B. Riley,** Ph.D. Oklahoma State, assistant professor.

Resignation: **George Brinkman,** assistant professor, to the University of Guelph.

UNIVERSITY OF KENTUCKY

Appointment: **Craig L. Infanger,** Ph.D. Washington State, assistant extension professor in rural development.

LOUISIANA STATE UNIVERSITY

Award: **Willard F. Woolf,** professor, received the Gamma Sigma Delta Teaching Award of Merit in May 1973.

THE UNIVERSITY OF MANITOBA

Retirement: **Sol Sinclair,** after 28 years, and named professor emeritus.

UNIVERSITY OF MASSACHUSETTS

Leave: **Bradford Deal Crossmon,** to the University of Puerto Rico, San Juan, Puerto Rico, for one-half year.

MICHIGAN STATE UNIVERSITY

Appointment: **Lester V. Manderscheid,** professor, as Associate Chairman.

Reassignment: **Lawrence Libby** is in Washington, D. C. during 1974 with Resources for the Future.

UNIVERSITY OF MINNESOTA

Retirement: **Selmer A. Engene,** professor, after 45 years of service.

UNIVERSITY OF MISSOURI-COLUMBIA

Appointments: **Donald Day,** Extension Farm Management Specialist, Mid-Mo area at Linn, Missouri; **Dale Schnarre,** Extension Farm Management Specialist, Mid-Mo area at Mexico, Missouri.

Honor: **Harold F. Breimyer,** Professor and Extension Economist, was named the Perry Foundation Professor of Agricultural Economics. He is the first to hold the M. G. and Johnnye D. Perry Foundation Professorship in Agricultural Marketing and Policy, newly established by that Foundation of Robstown, Texas. Terms of the Professorship include holding an annual nationwide Seminar in Agricultural Marketing and Policy.

Retirements: **Clyde Cunningham,** professor, after 28 years; **Lorene Wilson,** associate professor, after 25 years.

OHIO STATE UNIVERSITY

Appointment: **Dean Baldwin,** formerly at Miami University in Oxford, Ohio, as assistant professor.

RETURN: **Donald Larson**, from two years in Brazil as a member of the Ohio State University institution building contract.

OKLAHOMA STATE UNIVERSITY

LEAVE: **John W. Goodwin**, professor, to serve for six months as Deputy Commissioner of the Oklahoma State Department of Agriculture, working with the Southern United States Trade Association to develop international markets for Oklahoma products.

OREGON STATE UNIVERSITY

APPOINTMENTS: **Terry Nelson**, research assistant; **George L. Wyatt**, Extension community resource development specialist; **Douglas L. Young**, research assistant assigned to OSU/AID Weed Control Project in Recife, Brazil.

LEAVE: **Velma M. Seat**, associate professor and extension food marketing specialist, four-month sabbatical beginning February 1, 1974.

NEW ASSIGNMENT: **Emery N. Castle**, professor and Dean, Graduate School, has been named a member of the Oregon State Water Resources Board by Governor Tom McCall.

PURDUE UNIVERSITY

APPOINTMENT: **John Francis Marten**, assistant professor, farm management.

SOUTH DAKOTA STATE UNIVERSITY

APPOINTMENTS: **Richard K. Rudel**, Ph.D. Colorado State, assistant professor; **Donald Peterson**, Ph.D. Nebraska, assistant professor; **Robert L. Vertrees**, assistant professor.

STANFORD UNIVERSITY, FOOD RESEARCH INSTITUTE

APPOINTMENTS: **Omar L. Davies**, Ph.D. Northwestern, assistant professor; **Barry J. Edmonston**, Ph.D. Michigan, acting assistant professor and research demographer; **Raymond Leuthold**, associate professor at the University of Illinois, as visiting associate professor.

LEAVES: **Bruce F. Johnston**, professor, to Kenya as senior research fellow at the Institute for Development Studies at the University of Nairobi, from April 1974 to September 1975; **Pan A. Yotopoulos**, professor, to Honolulu, Hawaii, as senior research fellow at the East-West Technology and Development Institute, East-West Center, January–August 1974.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

APPOINTMENTS: **David Paul Miller**, M.S., and **Dilip C. Pendse**, Ph.D., research associates, both formerly at Oregon State.

RETIREMENT: **Kenneth E. Loope**, associate professor, after 37 years' service as Extension farm management specialist.

WASHINGTON STATE UNIVERSITY

APPOINTMENT: **Robert W. Wilcox**, formerly with the Ford Foundation in India, as Extension Economist.

LEAVE: **LeRoy R. Rogers**, to Australia for one year beginning February 1, 1974, as visiting professor at the University of New England, Armidale, New South Wales.

WEST VIRGINIA UNIVERSITY

APPOINTMENT: **Homer C. Evans**, as Acting Dean of the College of Agriculture and Forestry and Acting Director of the Agricultural Experiment Station during the convalescence of Dean Robert S. Dunbar, Jr.

UNIVERSITY OF WISCONSIN

LEAVES: **Duncan Harkin**, for two years beginning September 1973, on a project sponsored by the Land Tenure Center and the Agency for International Development; he will be working on agrarian reform in the Philippines; **Adlowe Larson**, for two years beginning June 1973, as project coordinator for the Midwestern University Consortium for International Activity (MUCIA) at Gadjah Mada University in Jogakarta, Indonesia.

RESIGNATION: **Richard Vilstrup**, resigned as Program Leader for Agriculture Agri-business, Extension, and is returning to the Meat and Animal Science Department beginning January 1, 1974.

RETIREMENT: **Raymond J. Penn**, Professor Emeritus, retired December 31, 1973, after 27 years of service.

OTHER APPOINTMENTS

James E. Angus, Ph.D. Minnesota, Ministry of Urban Affairs, Ottawa, Canada.

Tulio Barbosa, Ph.D. Purdue, associate professor, Universidade Federal de Vicosa, Vicosa, Minas Gerais, Brazil.

T. Roy Bogle, Ph.D. Missouri, Area Extension Economist, Kansas State University, Garden City.

Teunis de Boon, Ph.D. Florida, as marketing director with the Central Soya Company, Inc., Provimi, Portugal.

Evonir B. deOliveira, Ph.D. Purdue, associate professor, Universidade Federal de Vicosa, Vicosa, Minas Gerais, Brazil.

Kenneth Dobbins, M.S. Missouri, Statistical Reporting Service, USDA, in Cheyenne, Wyoming.

Richard Eggers, M.S. Missouri, Federal Land Bank, Sedalia, Missouri.

Joachim G. Elterich, associate professor at the University of Delaware, on exchange with the University of Kiel, Holzkoppelweg 4, Germany, Department of Agricultural Policy and Marketing, from January through August 1974.

Eugene E. Gerke, M.S. Purdue, as Food Economist, Supermarket Institute Inc., Chicago, Illinois.

John Jackson, M.S. Wyoming, Economist, Water

Planning Department, State Engineer's Office, Cheyenne, Wyoming.

Bob Johnmeyer, M.S. Missouri, Federal Land Bank, Jefferson City, Missouri.

Phil Kiner, M.S. Wyoming, Economist, Department of Administration and Fiscal Control, Capitol Building, Cheyenne, Wyoming.

Timothy Lawrence, M.S. Missouri, Eastman Kodak, Rochester, New York.

Lowell A. Lumpkin, M.S. Purdue, Operations Research Assistant, Land O' Lakes, Minneapolis, Minnesota.

Elizabeth A. Maxwell, M.S. Purdue, Brand Assistant, Procter & Gamble, Cincinnati, Ohio.

Ron Mueller, M.S. Missouri, Federal Land Bank, Cameron, Missouri.

Kalonji Ntalaja, Ph.D. Missouri, professor, Department of Economics, University Nationale du Zaire, Kinshasa.

Duane Olsen, Ph.D. Missouri, assistant professor, Department of Agricultural Economics, University of Nebraska, Lincoln.

Wayne Olson, Ph.D. Missouri, Director Trading Division, Commodity Exchange Authority, Washington, D. C.

Lalit Pati, Ph.D. Missouri, professor, Orissa University of Agriculture and Technology, Bhubaneswar, India.

Bob Retzlaff, Ph.D. Missouri, Extension Farm Management Specialist, Scottsbluff Experiment Station, Mitchell, Nebraska.

Joe Roetheli, M.S.A. Florida, Research Associate, Department of Agricultural Economics, University of Idaho, Moscow, Idaho.

James W. Shatava, Ph.D. Minnesota, assistant professor, Wisconsin State University, River Falls, Wisconsin.

Ronald Stout, M.S. Missouri, Armour and Company, Monroe, North Carolina.

Phiphit Suphaphiphat, Ph.D. Missouri, Applied Scientific Research Corporation of Thailand, Bangkok.

Keith Vickers, M.S. Missouri, Manager of Cooperative Development Division IV (Nebraska) Farmland Industries, Lincoln.

Carlos A. Zulberti, Ph.D. Cornell, International Development Research Centre, working with a small farm development project in Colombia.

OBITUARIES

Wylie D. Goodsell, 68, recently retired Department of Agriculture economist, died on December 27, 1973, from injuries sustained in an automobile accident near Logan, Utah.

Born in Weston, Idaho, Goodsell received bachelor's and master's degrees in science from the University of Idaho. He worked for USDA's Soil Conservation Service in 1934 while assigned as a research assistant at the University of Idaho. From 1934–38 he was a research assistant and then instructor at Iowa State University.

He went to Washington in 1938 to work with the Bureau of Agricultural Economics. His duties involved establishing major statistical series that served as barometers on the state of important types of farms across the country. These studies contributed greatly to the solution of agricultural adjustment problems during and after World War II.

During his 30 years with the USDA, Goodsell served as assistant chief of the cost, income, and efficiency branch of the Economic Research Service, and for many years was an instructor in farm management and production economics at USDA's Graduate School. He also served as a fisheries and game management expert for the United Nations and the Agency for International Development in Italy, the Near East, the Far East, and South America. He wrote a number of reports on livestock ranches and the sheep industry.

Goodsell had long been active in the Church of Jesus Christ of Latter-day Saints, serving in a number of high positions.

He is survived by his wife, three sons, a daughter, and his mother.

James Gray Maddox, 66, emeritus professor, North Carolina State University, died December 15, 1973, of cancer.

Maddox was born and raised on a small farm in Arkansas, and he devoted his life to bettering the economic conditions of rural people, particularly the rural poor.

His earliest professional experience was as Director of the Rural Rehabilitation Program of the Farm Security Administration. Later he served with the Rockefeller-financed American International Association, and he was a member of the American University's field staff as a Latin American Specialist.

Maddox joined the faculty at North Carolina State University in 1958 and devoted his time to teaching and studying the problems of economic development of the South. He served as research director for a four-year study financed by the Twentieth Century Fund and was the major author of the resulting book, *The Advancing South: Manpower Prospects and Problems.* In addition to this significant work, he published many other papers and presented countless talks dealing with the problems of the South.

Agricultural policy was a major concern, and he was a Director of the Agricultural Policy Institute at North Carolina State University, an agency devoted to educational activities related to policy and adjustment problems of the South.

Maddox graduated from the University of Arkansas, studied at the London School of Economics, and received his doctorate from Harvard University. He was elected a Fellow in the American Agricultural Economics Association in 1969.

Lynn S. Robertson, 83, professor at Purdue University for 60 years, died on December 14, 1973, in West Lafayette, Indiana.

A native of Minnesota, Robertson was a professional pioneer and the first Purdue agricultural economist. He received his B.S. from the University of Minnesota in 1914, his M.S. from Purdue in 1930, and Ph.D. from Cornell in 1937. He began his career at Purdue as a farm management demonstrator in 1914. His early work in financial records of Indiana farms was used to teach management principles to farmers. He also initiated accounting instruction for elementary pupils in rural schools. His extension work lasted until 1928 when the research program was begun under his leadership. He authored several widely used books, including two on farm management and one on research methodology. His latest, *A History of Agricultural Economics at Purdue University,* was just published. His many research publications and wide teaching range set the standards for graduate study in the department.

He was Assistant Head of the Department of Agricultural Economics from 1928–1958; Visiting Professor, University of the Philippines, 1953–54; Chief of Party, Purdue-Brazil Project, 1958–61; Visiting Professor, Biarritz American University, Biarritz, France, after World War II; and Visiting Professor, Garrett Institute for ministers at Northwestern University.

Robertson continued an active and alert retirement, contributing his services to the community. In 1965 he authored *Aunt Dora's Treasure Chest,* a book of gleanings from his family background.

His wife Adella Caroline Pettersen, whom he married in 1915, survives him, along with their children, four sons and one daughter.

ERRATA

In reference to "On the Incongruity of Program Objectives and Project Evaluation: An Example from the Reclamation Program," by Daniel W. Bromley and Bruce R. Beattie [*Am. J. Agr. Econ.* 55:472–476, Aug. 1974], the authors make the following correction: The area presently irrigated by the Bureau of Reclamation Program in the 17 western states is approximately 8.9 million acres, *not* 33 million acres [p. 472].

In reference to "A Framework for Comparing the Efficiency of Futures Markets," by Tetteh A. Kofi [*Am. J. Agr. Econ.* 55:584–594, Nov. 1973], the author adds the following acknowledgments which were unintentionally omitted in his original manuscript: The author is especially grateful to Roger W. Gray and Holbrook Working at Stanford and W. G. Tomek at Cornell who commented on earlier versions of a larger manuscript from which this article was culled. Paul H. Cootner, William O. Jones, C. Peter Timmer, Pan A. Yotopoulos, and anonymous reviewers also provided useful comments. The author is also grateful to Liu-Hsiung Chuang for able research assistance.

DOCTORAL DEGREES IN AGRICULTURAL ECONOMICS CONFERRED IN 1973, BY SUBJECT AREA

CATEGORIES

I. Agricultural Data
II. Agricultural Economics, General
III. Agricultural Finance, Capital, Credit
IV. Agricultural Income
V. Agricultural Labor; Rural Manpower
VI. Agricultural Products: Demand, Supply, Prices
VII. Economic Development, Growth, and Planning
VIII. Environmental Economics
IX. Food and Consumer Economics
X. General Economics
XI. Human Resource Development
XII. Industrial Organization
XIII. Marketing and Location
XIV. Natural Resource Economics
XV. Production Economics and Management
XVI. Public Policy and Programs
XVII. Regional Economics
XVIII. Research Methodology
XIX. Technological Change
XX. Trade
XXI. Other

I. AGRICULTURAL DATA

L. Don Lambert, B.S. Iowa State University, 1952; M.S. Michigan State University, 1964; Ph.D. Michigan State University, *Regional Trends in the Productivity of American Agriculture.*

Lawrence N. Smith, B.S. Cornell University, 1953; M.S. Purdue University, 1970; Ph.D. Purdue University, *Remote Sensing Requirements, Impact and Benefits in the Soybean Market and in the Economy.*

II. AGRICULTURAL ECONOMICS, GENERAL

Fernando Bento Homem de Melo, B.S. Universidade de Sao Paulo, 1967; M.E. North Carolina State University, 1971; Ph.D. North Carolina State University, *An Analysis of the World Economy in 1980.*

James Dean Howell, B.S.A. Purdue University, 1964; M.S. Ohio State University, 1971; Ph.D. Ohio State University, *Large Farm Organization in East Central Ohio.*

Mario Valderrama, B.S. Facultad the Ingenieria Agronomica, Universidad Nacional de Colombia, 1962; M.S. University of Nebraska-Lincoln, 1969; Ph.D. University of Nebraska-Lincoln, *Economics of Selected Inputs on Small and Large Farms of the Sabana of Bogota, Colombia.*

III. AGRICULTURAL FINANCE, CAPITAL, CREDIT

Chain S. Barla, B. Com. University of Rajasthan, Jaipur, 1957; M.A. University of Rajasthan, Jaipur, 1959; M.S. Michigan State University, 1970; Ph.D. Michigan State University, *An Analysis of Cooperative Agricultural Credit Institutions in India: A Case Study of the Primary Credit Societies in Rajasthan.*

Gary Lee Benjamin, B.S. Michigan State University, 1966; M.S. Michigan State University, 1968; Ph.D. University of Illinois, *An Analysis of the Structure and Functions of Correspondent Banking: Implications for Financing Agriculture in Illinois.*

Maurice Henry Brucker, B.S. University of Illinois, 1964; M.S. Cornell University, 1967; Ph.D. University of Illinois, *A Computer-Based Retirement Planning System for Farmers with Low Income.*

Wayne A. Hayenga, B.S. University of Illinois, 1964; M.S. University of Illinois, 1969; Ph.D. Michigan State University, *The Effects of Bank Mergers on Financial Services Available to Rural Michigan Residents.*

Richard L. Trimble, B.S. University of Missouri, 1968; M.S. University of Illinois, 1970; Ph.D. Michigan State University, *An Economic Analysis of the Effect of Monetary Policy on the Beef Industry.*

Chyau Tuan, B.S. Taiwan Provincial Chung Hsing University, 1967; M.S. Ohio State University, 1970; Ph.D. Ohio State University, *Determinants of Financial Savings in Farmers' Associations in Taiwan 1960–1970.*

IV. AGRICULTURAL INCOME

John Bartram Penson, Jr., B.S. Southern Illinois University, 1965; M.S. Southern Illinois University, 1967; Ph.D. University of Illinois, *An Aggregate Income and Wealth Model for the U. S. Farm Sector: Its Description and Application to Policy Analysis.*

Donald Lee Peterson, B.A. Mankato State College, 1965; M.A. Mankato State College, 1967; Ph.D. University of Nebraska-Lincoln, *An Evaluation of the Feasibility of Increasing the Incomes of Small Farm Operators by Working on Larger Commercial Farm Units.*

V. AGRICULTURAL LABOR; RURAL MANPOWER

James Carey Cato, B.S. Texas Technological College, 1967; M.S. Texas Technological College, 1968; Ph.D. University of Florida, *The Effect of Resource Investment Programs on Labor Employment.*

Conrad Franz Fritsch, B.A. Arizona State University, 1967; M.S. Cornell University, 1968; Ph.D. Cornell University, *An Evaluation of the Economic Effects on New York Agriculture from the Exten-*

sion of Unemployment Insurance to the Agricultural Sector.

Herman Frederick Gallasch, Jr., B.S. Hampden-Sydney College, 1966; M.E. North Carolina State University, 1967; Ph.D. North Carolina State University, *The Impact of Minimum Wage Legislation on the Farm Labor Market.*

Wade Lewis Griffin, Sr., B.S. Texas Technological University, 1967; M.S. Texas Technological University, 1969; Ph.D. Oregon State University, *The Relationship Among Income Labor Productivity, Property Taxes and Migration, U. S. Agriculture, 1957–1970.*

Bharat Jhunjhunwala, B.S. Kampur University, 1969; M.S.A. University of Florida, 1971; Ph.D. University of Florida, *Agricultural Mechanization, Rural Income Distribution and Unemployment in Faizabad District, East Uttar Pradesh.*

Nikolaos S. Martinos, Agricultural College of Athens, Dip.; M.S. Iowa State University; Ph.D. Iowa State University, *Economic Models of the Labor Market in the Farm Sector of the North Central Region of the United States, B. The Demand for Farm Labor in the United States.*

Samuel Manley Strong, B.S. University of New England, 1968; M.S. University of Illinois, 1971; Ph.D. University of Illinois, *An Optimal Control Approach to the Off-Farm Labor Migration Problem.*

Robert W. Watada, B.A. University of Colorado, 1964; A.M. Colorado State College, 1967; Ph.D. University of Hawaii, *Income Differential and Occupational Choice: Some Methodological Considerations for Manpower Planning.*

VI. AGRICULTURAL PRODUCTS: DEMAND, SUPPLY, PRICES

Abu Asgar Ahsan, B.Ag. University of Dacca, 1963; M.Ag. University of Dacca, 1965; M.S. University of Hawaii, 1973; Ph.D. University of Hawaii, *Economic Analysis of Rice Production in Bangladesh.*

Calvin Leon Brints, B.S. Texas Technological College, 1969; M.S. University of Minnesota, 1972; Ph.D. University of Minnesota, *The Economics of Information in Purchasing Feed and Fertilizer in Minnesota.*

Donald Gray Chafin, B.S. Virginia Polytechnic Institute, 1962; M.S. Ohio State University, 1964; Ph.D. Ohio State University, *Economic Analysis of Futuristic Beef Cattle and Forage Production Systems.*

Muhammad Ali Chaudhary, B.Sc. University of the Panjab, 1961; M.Sc. West Pakistan Agricultural University, 1965; M.S. University of Hawaii, 1969; Ph.D. University of Hawaii, *An Economic Analysis of the Demand and Supply for Nuts in the United States.*

Thomas E. Elam, B.S. Union University, 1969; M.S. University of Tennessee, 1971; Ph.D. University of Tennessee, *A Monthly Econometric Model of the U. S. Beef-Pork Economy.*

David P. Elliott, B.A. State University of New York, 1962; M.S. University of Hawaii, 1970; Ph.D. University of Hawaii, *Effects of the Enlarged EEC on the Danish Pigmeat Export Industries.*

Richard Harris Goldman, B.A. Bucknell University, 1963; M.A. University of Pennsylvania, 1964; Ph.D. Stanford University, *The Causes and Policy Implications of Temporal Rice Price Formation in Indonesia.*

Teketel Haile-Mariam, B.Sc. Haile Selassie University, 1969; Ph.D. Stanford University, *The Production, Marketing, and Economic Impact of Coffee in Ethiopia.*

Osman Abdel-Rahman Hakim, B.S. University of Khartoum (Sudan), 1959; M.S. University of Arizona, 1962; Ph.D. University of Arizona, *The Effects of the United States Cotton Policy on the World Market for Extra-Long Staple Cotton.*

S. J. Kalantar, B.S. University of Pahlavi, Iran, 1962; M.S. University of Pahlavi, Iran, 1963; Ph.D. University of Arizona, *Interregional Price Flexibilities and Structural Changes in the United States Beef Industry.*

George E. Kennedy, B.A. University of British Columbia, 1968; M.S. University of Minnesota, 1970; Ph.D. Purdue University, *A Simulation Analysis of Alternative Schemes to Stabilize Hog-Pork Prices.*

Pushpa Mathema, B.A. Tri-Chandra College, 1961; M.A. Tribhuwan University, 1963; Ph.D. University of Alberta, *Economic Analysis of Retail Prices of Cereal Grains in Nepal.*

Karl Dean Meilke, B.S. Washington State University, 1968; Ph.D. University of Minnesota, *The Demand for Animal Feed: An Econometric Method.*

Pal Yong Moon, B.S. Woosuk University, 1963; M.S. Korea University, 1967; Ph.D. Oregon State University, *An Analysis of Foodgrain Market in Korea.*

Walter M. Myers, B.S. Colorado State University, 1967; M.S. Colorado State University, 1969; Ph.D. Oklahoma State University, *Application of the Economic Model, Distributed Lag, to Forecasting Slaughter Cattle Price.*

Wayne Olson, B.S. University of Nebraska, 1957; M.S. University of Nebraska, 1958; Ph.D. University of Missouri, *A Review and Reappraisal of Speculative Limit Establishment Procedures as Applied to the Chicago Board of Trade Wheat, Corn, and Soybean Markets Under Non-Crisis Conditions.*

Kao-Twan Ong, B.S. National Taiwan University, 1963; M.S. National Taiwan University, 1966;

Ph.D. University of Illinois, *Quantitative Analysis of Applying Random Coefficient Regression Model to the Short-Run Fluctuations for Hogs.*

Arthur F. Parker, Jr., B.A. Clemson University, 1966; M.S.A. University of Florida, 1968; Ph.D. University of Florida, *An Econometric Analysis of the Florida Grapefruit Industry.*

Charles Everitt Powe, B.S. Mississippi State University, 1964; M.S. Mississippi State University, 1966; Ph.D. University of Florida, *A Model for Evaluating Alternative Policy Decisions for the Florida Orange Subsector of the Food Industry.*

Hormoz Saleh, B.S. Brigham Young University, 1967; Ph.D. Cornell University, *An Econometric Analysis of the Demand for Animal Protein in Iran.*

John Schamper, B.A. Michigan State University, 1968; Ph.D. University of Wisconsin-Madison, *An Analysis of Variables Affecting the Aggregate Production of Milk in the United States with Particular Emphasis on the Price of Beef.*

Rahim Shoraka, A.B. Morgan State College, 1968; M.A. University of Hawaii, 1969; Ph.D. University of Hawaii, *The Determination of Market Potential for a New Food Product: A Case Study of Guava.*

Phiphit Suphaphiphat, B.S. Chulalongkorn University, Bangkok, Thailand, 1965; M.S. University of Hawaii, 1970; Ph.D. University of Missouri, *An Analysis of the Impact of the Changes in the Delivery Procedure of the Fresh Shell Eggs Futures Contract.*

Hovav Talpaz, B.A. The Hige Institute for Agriculture, Israel, 1963; Ph.D. Michigan State University, *Dynamic Decision Models in the Hog-Pork Subsector Production Process.*

Lloyd D. Teigen, B.S. Montana State University, 1967; M.S. Michigan State University, 1970; Ph.D. Michigan State University, *Costs, Loss, and Forecasting Errors: An Evaluation of Models for Beef Prices.*

VII. ECONOMIC DEVELOPMENT, GROWTH, AND PLANNING

Kathryn I. Abbassi, A.B. University of California, 1967; M.S. University of California, 1970; Ph.D. University of California, *Distributional Consequences of Growth.*

Amos A. Adesimi, B.S. University of Ife-Nigeria, 1966; M.A. Manchester University, England, 1968; Ph.D. University of Wisconsin-Madison, *The Prospects and Potentials of Groundnut Cultivation as a Means of Enhancing Economic Opportunities in the Rural Economy of Northern Nigeria.*

Glenn C. W. Ames, B.S. Mansfield State College, 1964; M.A. Northern Illinois State College, 1968; Ph.D. University of Tennessee, *Ryots' Reward: A Study of Production Credit Repayment Problems of Small Farmers in Mysore State, India.*

Edgardo Enrique Barandiaran, M.A. University of Minnesota, 1970; Ph.D. University of Minnesota, *The Control of Money and Bank Credit in Argentina.*

Tulio Barbosa, B.S. Federal University of Vicosa, 1963; M.S. Federal University of Vicosa, 1966; Ph.D. Purdue University, *A Normative Analysis of Land Reform Measures in the Priority Area of Rio de Janeiro, Brazil.*

Kwong-Yuan Chong, B.S. University of Illinois, 1966; M.S. University of Kentucky, 1969; Ph.D. Michigan State University, *A Simulation Policy Analysis of the Western Nigerian Cocoa Industry.*

Kenton Rex Corum, B.A. University of Washington, 1964; Ph.D. University of California, *The Demand for Human Resources in Agriculture in Relation to Government Price Policies in Economic Development: The Case of India.*

Melvin LeRoy Davis, B.S. California State Polytechnic College, 1966; M.S. Iowa State University, 1968; Ph.D. Colorado State University, *Rural Development in Colorado.*

Otto Charles Doering, III, B.A. Cornell University, 1963; M.S. London School of Economics and Political Science, 1965; Ph.D. Cornell University, *Malaysian Rice Policy and the Muda River Irrigation Project.*

Raul Fiorentino, Graduate, University of Buenos Aires, 1968; M.S. University of California-Davis, 1970; Ph.D. University of California-Davis, *A Structural Approach to Agricultural Poverty Policy in Northeast Argentina.*

Tarafder R. Islam, B.A. Magura College, 1958; M.A. Rajshahi University, Bangladesh, 1961; Ph.D. Michigan State University, *Alternative Low-Lift Pump Irrigation Policies in Bangladesh: An Economic and Financial Analysis.*

Charles R. Kerley, B.S. Tennessee Technological University, 1967; M.S. University of Tennessee, 1970; Ph.D. University of Tennessee, *Delineating Tennessee Into Functional Economic Areas.*

Arumugan Kunasingham, B.S. University of Ceylon, 1955; M.S. University of Hawaii, 1968; Ph.D. University of Hawaii, *Economics of New Land Settlement Projects in Ceylon.*

Olasupo O. Ladipo, B.S. Cornell University, 1965; M.S. Cornell University, 1966; Ph.D. Michigan State University, *General System Analysis and Simulation Approach: A Preliminary Application to Nigerian Fisheries.*

Wuu-Long Lin, B.S. National Taiwan University, 1965; M.S. Kansas State University, 1968; Ph.D. Stanford University, *Economic Interactions in Taiwan: A Study of Sectoral Flows and Linkages.*

Chung-Chi Lu, B.A. Taiwan Provincial Chung-Hsing University; M.S. Iowa State University;

Ph.D. Iowa State University, *The Role of Food Aid, Agricultural Development and Capital Formation in Economic Development: A Case Study in Taiwan.*

Gerald Ira Nehman, B.S. Rutgers University, 1964; M.S. University of Rhode Island, 1966; Ph.D. Ohio State University, *Small Farmer Credit Use in a Depressed Community of Sao Paulo, Brazil.*

Kalonji Ntalaja, B.S. Ecole Nationale d'Administration, 1966; M.S. Washington University, 1969; Ph.D. University of Missouri, *Decision Making Process of African Farmers: A Theoretical Approach.*

Ernest Nzekio, B.S. Southern Illinois University, 1969; Ph.D. University of Wisconsin-Madison, *Stability, Export Taxation, and Economic Development: The Role of Cocoa Marketing Boards and Cocoa Stabilization Funds in Nigeria, Ghana, Ivory Coast, and Cameroun.*

Roop Narayan Pandey, B.S. Uttar Pradesh Agricultural University, 1963; M.S. Uttar Pradesh Agricultural University, 1969; Ph.D. University of Illinois, *Livestock and Crop Production Patterns in Uttar Pradesh, India, and Projections of Alternative Livestock Development Possibilities.*

Iby Arvatti Pedroso, B.S. Escola Superior de Agricultura "Luiz de Queiroz," 1965; M.S. Cornell University, 1968; Ph.D. Ohio State University, *Resource Accumulation and Economics of Scale in Agriculture—The Case of Sao Paulo, Brazil.*

Edwin Chappell Price, Jr., B.S. University of Florida, 1966; M.A. Yale University, 1968; Ph.D. University of Kentucky, *The Aggregate Bovine Supply in Northeast Thailand.*

Charles Alexander Robertson, B.S. University of Glasgow, 1953; M.S. Michigan State University, 1963; Ph.D. Cornell University, *Economic Analysis of Ground Water Irrigation in Nueva Ecija, Philippines.*

S. Nicholas Samuel, B.A. Aquinas University, Colombo, Sri Lanka, 1964; M.S. Michigan State University, 1971; Ph.D. Michigan State University, *Income Redistribution Through Technological Changes in Agriculture: Implications for Sri Lanka's Paddy Subsector.*

John Houston Sanders, Jr., B.S. Dartmouth College, 1963; M.S. University of Kentucky, 1967; Ph.D. University of Minnesota, *Mechanization and Employment in Brazilian Agriculture, 1950–1971.*

Michael Gerald Galton Schluter, B.A. Durham University, 1968; M.S. Cornell University, 1971; Ph.D. Cornell University, *The Interaction of Credit and Uncertainty in Determining Resource Allocation and Incomes on Small Farms, Surat District, India.*

Kenneth Howard Shapiro, B.S. Cornell University, 1963; M.S. University of Maryland, 1966; Ph.D. Stanford University, *Efficiency and Modernization in African Agriculture: A Case Study in Geita District, Tanzania.*

Narendra Prasad Sharma, B.S. University of Hawaii, 1968; M. S. Rutgers University, 1970; Ph.D. Virginia Polytechnic Institute and State University, *An Interindustry Framework for Estimating the Economic Impacts of Alternative Development Strategies for Virginia's Eastern Shore.*

Clyde G. Swenson, B.A. University of Minnesota, 1964; M.S. University of Minnesota, 1967; Ph.D. Michigan State University, *The Effect of Increases in Rice Production on Employment and Income Distribution in Thanjavur District, South India.*

Jorge Augusto Torres, Graduate, Agrarian University, La Molina, 1965; M.S. University of California, 1970; Ph.D. University of California, *Input-Output Models and Structural Analysis of the Peruvian Economy.*

Hiroshi Tsujii, B.S. Kyoto University, 1964; M.S. University of Illinois, 1969; Ph.D. University of Illinois, *An Econometric Study of Effects of National Rice Policies and the Green Revolution on National Rice Economies and International Rice Trade Among Less Developed and Developed Countries: With Special Reference to Thailand, Indonesia, Japan, and the United States.*

William Windsor Wade, B.S. Spring Hill College, Mobile, Alabama, 1963; M.S. University of Minnesota, 1967; Ph.D. University of Minnesota, *Institutional Determinants of Technical Change and Agricultural Productivity Growth: Denmark, France, and Great Britain, 1870–1965.*

VIII. ENVIRONMENTAL ECONOMICS

Muhammad Ashraf, B.S. West Pakistan Agricultural University, 1962; M.S. West Pakistan Agricultural University, 1964; Ph.D. University of Massachusetts, *Optimum Dairy Farm Organization in Relation to Water Quality in Massachusetts.*

Jagjit Singh Brar, B.S. Panjab University, 1960; M.S. Panjab University, 1966; Ph.D. Oregon State University, *Costs of Alternative Pollution Control Policies Affecting Open Field Burning in the Willamette Valley of Oregon: A Study in Measurement.*

Harold William Gaede, Jr., B.S. Rutgers University, 1966; M.S. University of Massachusetts, 1968; Ph.D. University of Massachusetts, *Economic Impact of Pollution Reducing Manure Disposal Systems on the Massachusetts Egg Industry.*

John Clark Gamble, B.S. Iowa State University, 1963; M.S. Auburn University, 1969; Ph.D. University of Illinois, *Economic Evaluation of the Impact of Alternative Environmental Regulations* *and Waste Management Systems on Illinois Hog Producers.*

Christopher John Neville Gibbs, B.S. University of London, 1966; Ph.D. Oregon State University, *An Economic Study of Sewage Transmission and Land Uses: An Empirical Application.*

John August Jaksch, B.S. Southern Oregon College, 1966; M.S. Oregon State University, 1969; Ph.D. Oregon State University, *Outpatient Medical Costs Related to Air Pollution in the Portland-Vancouver Area.*

Carl Lennis Pherson, B.S. University of Minnesota, 1967; Ph.D. University of Minnesota, *Economics of Alternative Waste Management Systems Complying with Pollution Control Regulations on Beef Feedlots in Southwestern Minnesota.*

Robert A. Richardson, B.S.A. University of New England, 1967; M.S. Purdue University, 1971; Ph.D. Purdue University, *An Analysis of the Generation of Household Solid Waste Residuals.*

Kenneth Joseph Roberts, B.S. Louisiana State University, 1966; M.S. Louisiana State University, 1969; Ph.D. Oregon State University, *Economic and Environmental Trade-offs in an Estuarine Based Economy: A Modified Input-Output Analysis of Clatsop County, Oregon.*

Herbert David Schellenberg, B.S.A. University of Manitoba; M.S. University of Manitoba; Ph.D. Iowa State University, *Identification, Measurement, and Incorporation of Environmental Quality Objectives in Natural Resource Development.*

IX. FOOD AND CONSUMER ECONOMICS

Norman Eugene Payne, B.S. Cornell University, 1969; M.S. Cornell University, 1970; Ph.D. Cornell University, *An Economic Evaluation of School Lunch Systems.*

Michael Sunshine, B.S. University of California, 1965; Ph.D. Michigan State University, *Abuse of Warranty Laws as a Contributing Factor to Consumer Problems.*

Kenneth Gustaf Swanberg, B.A. Harvard College, 1963; M.S. Cornell University, 1971; Ph.D. Cornell University, *The Potential Impact on Nutritional Status of Reducing Marketing Costs Through Marketing System Manipulation in Low Income Developing Countries.*

Sachiko Yamashita, B.S. Ochanomizu University, 1955; M.S. University of Minnesota, 1969; Ph.D. University of Minnesota, *An Exploration of the Economics of Taste and Demand for Food.*

X. GENERAL ECONOMICS

Kwang-Siung C. Ling, B.S. National Taiwan University, 1967; M.S. University of Connecticut, 1970; Ph.D. University of Connecticut, *Optimal Mix of Fiscal and Monetary Policy for Stabilization and Growth: An Optimal Control Theory Approach.*

XI. HUMAN RESOURCE DEVELOPMENT

Gary Thomas Barnes, B.A. University of Oklahoma, 1965; Ph.D. North Carolina State University, *An Econometric Analysis of the College Going and College Choice Decision.*

Carlos Alberto Benito, Graduate, National University of Cuyo, Argentina, 1964; M.S. University of California-Davis, 1971; Ph.D. University of California-Davis, *Manpower Development and Labor Earnings in Humboldt County—An Econometric Model.*

Samuel Meade Cordes, B.S. South Dakota State University, 1967; Ph.D. Washington State University, *The General Practitioner in Rural Washington: Opinions Characteristics, and Comparative Productivity Among Practice Sizes.*

David L. Debertin, B.S. North Dakota State University, 1969; M.S. North Dakota State University, 1970; Ph.D. Purdue University, *An Econometric Investigation of the Provision for Public Education in Indiana.*

Lee Anderson Lillard, III, B.S. University of Texas-Arlington, 1966; M.A. Southern Methodist University, 1968; M. Stat. North Carolina State University, 1970; Ph.D. North Carolina State University, *An Explicit Solution to the Human Capital Life Cycle of Earnings Model and Its Application to Earnings Distributions.*

Robert Bruce Mackey, B.S. Lewis and Clark College, 1967; M.A. Washington State University, 1969; Ph.D. Washington State University, *The Participation of Rural Residents in Washington's Aid to Families with Dependent Children (AFDC) Program.*

Ali Mohammad, B.S. Agricultural College, 1965; M.S. University of Alberta, 1969; Ph.D. Washington State University, *Frontier Migration to Industrial Areas in West Pakistan: A Case of Temporary Migration with Return Flow of Funds.*

Larry Clinton Morgan, B.S. University of Kentucky, 1964; M.S. University of Kentucky, 1966; Ph.D. University of Kentucky, *An Economic Analysis of Out-Migration from a Depressed Rural Area.*

Duane Olsen, B.S. University of Minnesota, 1961; M.S. Purdue University, 1963; Ph.D. University of Missouri, *The Inmigration Response to the Industrialization of Four Distressed Regions.*

Gerald Emmett Plato, B.S. University of Georgia, 1965; M.S. University of Georgia, 1968; Ph.D. The Pennsylvania State University, *Effects of Selected Disadvantaging Characteristics on the Hourly Earnings and Labor Force Participation of Household Heads.*

Hans Dietrich Radtke, B.S. Portland State University, 1964; M.S. Montana State University, 1968; Ph.D. Oregon State University, *The Allocation of Health-Producing Resources in the Pacific Northwest.*

Richard Douglas Robbins, B.S. North Carolina A & T State College, 1964; M.S. North Carolina State University, 1968; Ph.D. North Carolina State University, *Costs and Returns to Occupational Education.*

Michael Samuel Salkin, B.S. University of California, 1968; M.S. University of California-Davis, 1970; Ph.D. University of California-Davis, *Migration and Migration Predictions in the Western Region of the United States.*

Jackie F. Shaner, B.S. University of Arkansas, 1965; M.S. University of Missouri, 1968; Ph.D. North Carolina State University, *Subsidization of Public Higher Education in North Carolina.*

Richard Lynn Shortlidge, Jr., B.A. University of Florida, 1964; M.S. Cornell University, 1970; Ph.D. Cornell University, *The Employment and Earnings of Agricultural Graduates in India: A Benefit Cost Case Study of G. B. Plant College of Agriculture and Technology.*

Thomas Franklin Stinson, B.S. Washington State University, 1964; M.S. Syracuse University, 1965; Ph.D. University of Minnesota, *The Demand for Education: An Hedonic Approach.*

Wesley Weidemann, B.S. University of Wisconsin-Madison, 1967; M.S. University of Kentucky, 1968; Ph.D. University of Wisconsin-Madison, *Migration: Economic and Noneconomic Determinants and the Private Economic Benefits.*

XII. INDUSTRIAL ORGANIZATION

John Raymond Brooker, B.S. University of Florida, 1961; M.S.A. University of Florida, 1963; Ph.D. University of Florida, *Systems Analysis of the United States Winter Fresh Tomato Industry.*

Yueh-Yun Cheng O'Brien, B.S. National Taiwan University, 1964; M.S. Washington State University, 1967; Ph.D. University of Illinois, *Intertemporal Equilibrium Models of a Monopoly and the Analysis of Tax Effects.*

James Wilson Owens, B.S. North Carolina State University, 1968; M.T.T. North Carolina State University, 1970; Ph.D. North Carolina State University, *Firm Efficiency and Market Structure Analysis of Merger Guidelines in the Textile Mill Products Industry.*

Ali Ben Zaid Salem, B.S. Ecole Nationale Superieure d'Agriculture de Tunis, 1967; M.S. Cornell University, 1970; Ph.D. Cornell University, *Firm Size and Changes in Industrial Structure: An Econometric Analysis of the Dairy Industry in New York State.*

XIII. MARKETING AND LOCATION

John Lamont Baritelle, B.S. University of California, 1964; M.S. University of California, 1966; Ph.D. Washington State University, *Supply Response and Marketing Strategies for the Washington Apple Industry.*

Wayne Allison Boutwell, B.S. Mississippi State University, 1966; M.S. Mississippi State University, 1968; Ph.D. Virginia Polytechnic Institute and State University, *An Analysis of Grain Storage in a Deficit Area.*

Michael Francis Bradley, B.A. University College, Dublin, 1967; M.S. University College, Dublin, 1969; Ph.D. Cornell University, *Proposal for Long-Term Apple Processing Marketing Contracts.*

Gerald R. Campbell, B.S. Ohio State University, 1967; M.S. Mexico State University, 1969; Ph.D. Michigan State University, *Procurement Contracting and Sow Leasing as Vertical Coordination Arrangements in the Hog-Pork Subsector.*

Dennis Merriam Conley, B.S. Iowa State University; M.S. Iowa State University; Ph.D. Iowa State University, *An Analysis of the Domestic and Foreign Distribution of U. S. Heavy Grains Under Alternative Assumptions Regarding Possible Future Supply, Demand and Transport Costs.*

Norberto Frigerio, B.S. Buenos Aires University, 1958; Ph.D. Michigan State University, *Alternative Wholesale Facility Arrangements for Fresh Fruits and Vegetables in the Buenos Aires Metropolitan Region.*

John D. Graham, B.S. University of Natal, South Africa, 1961; M.S. University of Natal, South Africa, 1966; Ph.D. Purdue University, *A Multiperiod Cash Management Analysis of Problems Facing a Commercial Meat Packing Firm.*

Gerald Emmett Grinnell, B.S. University of Kentucky, 1966; Ph.D. University of Kentucky, *Livestock Auction Markets in Kentucky: An Economic Analysis.*

Henry M. Hays, Jr., B.B.A. and B.A. Washburn University, 1966; M.A. Kansas State University, 1968; Ph.D. Kansas State University, *The Organization of the Staple Food Grain Marketing System in Northern Nigeria: A Study of Efficiency of the Rural-Urban Link.*

Larry Dean Jones, B.S. Ohio State University, 1968; M.S. Purdue University, 1971; Ph.D. Purdue University, *An Experimental Business Gaming Approach for Examining Behavior and Performance in the Food Retailing Industry.*

Ronald E. Jones, B.S. Auburn University, 1961; M.S. Auburn University, 1963; Ph.D. University of Tennessee, *Cost Analysis of Synthetic Model Lima Bean Freezing Plants.*

Paul Shen-tung Lee, B.S. Taiwan Provincial Chung-Hsing University, 1958; M.S. Taiwan Provincial

Chung-Hsing University, 1962; Ph.D. Washington State University, *An Econometric Analysis of the Wheat Markets of Taiwan and Japan.*

Donald McClatchy, B.S.A. Lincoln College, New Zealand, 1965; M.S.A. Lincoln College, New Zealand, 1969; Ph.D. Purdue University, *Combines in the Corn Belt: A Normative Study of Farm Machinery Demand.*

John Francis Marten, B.S. Iowa State University, 1966; M.S. Purdue University, 1970; Ph.D. Purdue University, *An Economic Analysis of the Future of the Liquid Feed Supplement Industry in Indiana.*

Fernando Martinez, Graduate, Catholic University of Chile, 1966; M.S. University of California, 1968; Ph.D. University of California, *An Economic Analysis of the Chilean Fresh and Canned Fruit Industries.*

Dale J. Menkhaus, B.S. Purdue University, 1967; M.S. Michigan State University, 1969; Ph.D. Purdue University, *The Effects of Environmental Legislation on the Structure of the Pesticide Industry: A Simulation Study.*

Alfred Leon Parks, B.S. Arkansas Agricultural and Mechanical College, 1967; M.S. University of Illinois, 1969; Ph.D. University of Illinois, *The Effects of Wage Contract Provisions in the Contracts of Wholesale Milk Drivers on Total Wage Payments and Unit Labor Delivery Costs in the Fluid Milk Industry.*

Anne Elizabeth Peck, B.S. Stanford University, 1969; M.A. Stanford University, 1970; Ph.D. Stanford University, *Futures Markets, Supply Response, and Price Stability.*

Charles Nelson Shaw, B.S. West Virginia University, 1961; M.S. West Virginia University, 1965; Ph.D. The Pennsylvania State University, *Economic Effects of Resale Price Regulation on Market Performance in the Fluid Milk Industry.*

Thomas Howard Stafford, B.A. Purdue University, 1968; M.S. Cornell University, 1970; Ph.D. Cornell University, *Methods and Costs of Distributing Beef to the Food-Service Industry.*

Veraphol Suvannunt, B.A. Chiang Mai University; M.S. Iowa State University; Ph.D. Iowa State University, *Measurement of Quantities and Prices of Product Qualities.*

J. Pablo Torrealba, B.S. Catholic University of Chile, 1968; M.S. Michigan State University, 1970; Ph.D. Michigan State University, *Improving the Organization of Fruit and Vegetable Production—Assembly Systems in the Coffee Zone of Colombia: A Case Study in the La Mesa Region.*

James Keith Wilkinson, B.S.A. University of Guelph, 1967; M.S. University of Kentucky, 1971; Ph.D. University of Kentucky, *Analysis of Retail Dairy Feed Markets and Buyer-Seller Procurement Practices in Selected Kentucky Counties.*

XIV. NATURAL RESOURCE ECONOMICS

Jon M. Conrad, B.S. University of Wisconsin-Milwaukee, 1968; M.A. University of Wisconsin-Madison, 1970; Ph.D. University of Wisconsin-Madison, *Uncertain Externality: The Case of Oil Pollution.*

Cornelis Waltherus Corssmit, B.S. International Institute of Tropical and Subtropical Agriculture, 1965; B.S. McGill University, 1967; M.S. University of Massachusetts, 1969; Ph.D. Washington State University, *An Analysis of Social Overhead Capital Expenditures in the Columbia Basin Irrigation Project.*

Arthur Berry Daugherty, B.S. West Virginia University, 1958; M.S. University of Massachusetts, 1960; Ph.D. The Pennsylvania State University, *Feasibility of Developing Regional Public Water Systems with Emphasis on the Municipal Authority Form of Organization.*

Robert H. Forste, B.S. Cornell University, 1958; M.S. University of Rhode Island, 1961; Ph.D. University of Massachusetts, *The Effects of Diminished Groundwater Supplies on Selected New Hampshire Industries.*

Alan Fox, B.S. Cornell University, 1957; M.S. Cornell University, 1962; Ph.D. Cornell University, *An Agricultural Land Use Model for New York State.*

Tirath R. Gupta, B.S. Punjab University, 1957; M.S. University of Delhi, 1959; Ph.D. University of Massachusetts, *Economic Criteria for Decisions on Preservation of Natural Resources with Special Reference to Freshwater Wetlands in Massachusetts.*

Gregory Clarence Gustafson, B.A. Washington State University, 1966; M.A. Washington State University, 1968; Ph.D. University of California. *The California Land Conservation Act of 1965, Economic Analysis of a New Tool of Land Use Policy.*

Clyde Frederick Kiker, B.A.E. University of Florida, 1962; M.S.E. University of Florida, 1965; Ph.D. University of Florida, *River Basin Simulation as a Means of Determining Operating Policy for a Water Control System.*

Robert Bruce McKusick, B.S. University of California-Davis, 1965; M.S. University of California-Davis, 1967; Ph.D. University of California-Davis, *An Economic Evaluation of Benefit Cost Analysis with Special Reference to the Derived Demand for Irrigation Water for Tree Fruits and Nuts, and Grapes in California.*

Mudziviri Takadiwa Nziramasanga, B.A. University of Connecticut, 1967; M.A. Stanford University, 1968; Ph.D. Stanford University, *The Copper Export Sector and the Zambian Economy.*

Ho-Sung Oh, B.S. Seoul University, 1964; M.S. University of Hawaii, 1970; Ph.D. University of Hawaii, *Economics of Urban Water Demand; A Case Study of The Honolulu Board of Water Supply.*

Ronald Anthony Oliveira, B.S. University of California, 1968; M.S. University of California-Davis, 1969; Ph.D. University of California-Davis, *An Econometric Analysis of Wilderness Area and Campground Use.*

Robert Martin Pope, Jr., B.S. College of Charleston, 1966; Ph.D. Clemson University, *Effects of Price Level and Price Change upon the Domestic Use of Water over Time.*

Leonard A. Shabman, B.S. University of Massachusetts, 1967; M.S. Cornell University, 1970; Ph.D. Cornell University, *Decision Making in Water Resource Development and the Potential of Multi-Objective Planning: The Case of the Army Corps of Engineers.*

Robert Michael Spann, B.S. North Carolina State University, 1970; M.E. North Carolina State University, 1970; Ph.D. North Carolina State University, *The Supply of Natural Resources: The Case of Oil and Natural Gas.*

Werner J. Sublette, B.S. Arizona State University, 1965; M.S. Arizona State University, 1967; Ph.D. University of Arizona, *Demand for and Value of Outdoor Recreation in the Salt-Verde Basin of Arizona.*

Tan Bock Thiam, B.Ag.Sc. University of Malaya, 1965; M.S. Cornell University, 1967; Ph.D. North Carolina State University, *Prices and Trade Prospects for Malaysian Palm Oil.*

XV. PRODUCTION ECONOMICS AND MANAGEMENT

George O. Abalu, B.S. University of Wisconsin; M.S. Iowa State University; Ph.D. Iowa State University, *Optimal Investment Decisions in Perennial Crop Production in Cameroon: A Dynamic Programming Approach.*

Muddathir Ali Ahmed, B.S. University of Khartoum (Sudan), 1961; M.S. University of Arizona, 1965; Ph.D. University of Arizona, *Electronic Data Processing as a Tool in Farm Management: A Case Study of Arizona Amap Users.*

William Lanny Bateman, B.B.A. Southern State College, 1966; M.S. University of Arkansas, 1969; Ph.D. Oklahoma State University, *An Economic Analysis and Comparison of Part-time and Full-time Beef Farm Operations in Eastern Oklahoma.*

Daniel Frank Capstick, B.S. Oklahoma State University, 1951; M.S. Oklahoma State University, 1953; Ph.D. Oklahoma State University, *Quadratic Programming Analysis of Farm Organizations in Northeastern Arkansas.*

Ying I. Chien, B.S. National Taiwan University, 1964; M.S. University of Manitoba, 1968; Ph.D. University of Kentucky, *Developing a Multi-period Linear Programming-Simulation Farm Firm Growth Model: Application to a Central Kentucky Beef Cattle Farm.*

Abiodun Alumuyiwa Falusi, B.S. University of Ibadan, 1968; M.S. Cornell University, 1970; Ph.D. Cornell University, *Economics of Fertilizer Distribution and Use in Nigeria.*

John A. Ginzel, B.S. Purdue University, 1964; M.S. Purdue University, 1966; Ph.D. Purdue University, *Computerized Budgetary Projection of Farm Plans Adaptable to Farm Accounting Systems.*

Allan J. Harris, B.S. University of Minnesota, 1962; M.S. North Dakota State University, 1967; Ph.D. Kansas State University, *Economic Incentives in Dryland Crop Share Leases, Western Kansas, 1951 and 1970.*

Roy Edward Hatch, B.S. Texas Technological University, 1961; M.S. Texas A & M University, 1963; Ph.D. Oklahoma State University, *Growth Potential and Survival Capability of Southern Plains Dryland Farms; A Simulation Analysis Incorporating Multiple-Goal Decision Making.*

Frederic Lee Hoff, B.S. Ohio State University, 1965; M.S. University of Missouri, 1968; Ph.D. University of Kentucky, *An Analysis of the Effect of Burley Tobacco Price and Quota Declines on Production and Income Adjustments.*

Rodney C. Kite, B.S. University of Wyoming, 1964; M.S. University of Wyoming, 1967; Ph.D. Purdue University, *An Interregional Analysis of Livestock Use of Selected Feed Ingredients.*

Wen-Rong Lin, B.S. Taiwan Provincial Chung-Hsing University, China, 1964; M.S. University of California-Davis, 1970; Ph.D. University of California-Davis, *Decisions under Uncertainty: An Empirical Application and Test of Decision Theory in Agriculture.*

Allan Eugene Lines, B.S. Cornell University, 1963; M.S. Cornell University, 1969; Ph.D. Purdue University, *A Computerized Model for Planning the Growth and Organization of Swine Farms.*

Telahun Makonnen, B.Sc. Haile Selassie I University, 1963; M.Sc. University of Minnesota, 1966; Ph.D. University of Alberta, *Interregional Competition in Ethiopian Agriculture.*

Thomas L. Mann, B.A. University of Illinois; M.S. University of Illinois; Ph.D. Iowa State University, *Economic Impact of Restricting Feed Additives in Livestock and Poultry Production.*

J. B. Penn, B.S. Arkansas State University, 1965; M.S. Louisiana State University, 1967; Ph.D. Purdue University, *Econometric Policy Models of Commodity Supply Response.*

W. Edward Schmisseur, B.S. University of Illinois, 1964; M.S. Purdue University, 1966; Ph.D. Purdue University, *Influence of Methods of Expansion, Financial Leverage Use and Constraints, Milk Prices, Milking and Housing Systems, and Herd and Crop Management on the Growth Rate of Corn Belt Dairy Farms.*

James Walter Shatava, B.A. University of Minnesota, 1966; M.S. University of Minnesota, 1968; Ph.D. University of Minnesota, *An Estimate of the Benefits Derived from the Use of Commercial Fertilizer and Pesticides in Agriculture.*

Derli Chaves Machado da Silva, Veterinarian, Federal University of Rio Grande do Sul, 1964; M.Sc. Inter-American Institute of Agricultural Sciences, 1969; Ph.D. Louisiana State University, *An Economic Analysis of Farm Organizations for Beef Cattle Production in the Southwest Louisiana Rice Area.*

Daniel B. Smith, B.S. Auburn University, 1963; M.S. University of Tennessee, 1965; Ph.D. University of Kentucky, *An Evaluation of the Competitiveness of Beef Cattle Production for Resource Use in Selected Areas of Kentucky.*

Dunstan Sylvester Christie Spencer, B.S. University of London, 1966; M.S. University of Illinois, 1969; Ph.D. University of Illinois, *The Efficient Use of Resources in the Production of Rice in Sierra Leone: A Linear Programming Study.*

Jay L. Strom, B.S. University of Minnesota, 1959; M.A. Purdue University, 1967; Ph.D. Purdue University, *Simulation of a Swine Breeding Herd.*

XVI. PUBLIC POLICY AND PROGRAMS

John Paul Combs, B.A. North Carolina State University, 1967; M.A. North Carolina State University, 1970; Ph.D. North Carolina State University, *The Economics of Information, Discrimination in the Real Estate Market, and the Open Housing Law of 1968.*

Steven R. Guebert, B.S. University of Illinois-Urbana, 1967; M.S. University of Illinois-Urbana, 1969; Ph.D. University of Wisconsin-Madison, *Farm Policy Analysis Within a Farm Sector Model.*

William Edgar Hardy, Jr., Virginia Polytechnic Institute and State University, 1968; M.S. Virginia Polytechnic Institute and State University, 1970; Ph.D. Virginia Polytechnic Institute and State University, *Determination of the Best Locations for Rural Health Outreach Clinics: An Economic Analysis Based on Virginia Planning District 10.*

Donald C. Hines, B.S. Mississippi State University, 1968; M.S. Mississippi State University, 1970; Ph.D. Kansas State University, *Public Primary and Secondary Education Costs in Kansas with Implications for Revenue Generation and Allocation.*

Geoffrey Harvey Jackson, B.Ag.Ec. University of New England, Australia, 1968; M.S. Cornell University, 1971; Ph.D. Cornell University, *Milk Supply Response and Some Regional Implications for Dairy Policy in the United States.*

Phillip Lynn Knox, B.S. Kansas State University, 1969; M.S. University of California, 1970; Ph.D. University of California, *The U. S. Beef Cattle Industry: A Policy Analysis with Costs of Adjustment Theory.*

Glenn L. Nelson, B.S. University of Minnesota, 1965; M.A. Stanford University, 1966; Ph.D. Michigan State University, *The Financing of Higher Education: With Specific Application to Michigan.*

John Rosine, B.A. Kansas State Teachers College, 1967; Ph.D. University of Wisconsin-Madison, *The Impact of U. S. Commodity Programs on the Farm Factor: An Aggregate Quantitative Approach.*

Tesfai Tecle, B.S. Haile Selassie University, 1968; M.S. Cornell University, 1971; Ph.D. Cornell University, *An Economic Evaluation of Agricultural Package Programs in Ethiopia.*

Jasper Allen Womach, B.S. Washington State University, 1968; M.A. Washington State University, 1971; Ph.D. Washington State University, *Income Transfers in Kind: An Evaluation of the National School Lunch Program in the State of Washington.*

XVII. REGIONAL ECONOMICS

James Edward Angus, B.S. McDonald College of McGill University, M.S. University of Massachusetts, 1968; Ph.D. University of Minnesota, *Spatial Distribution of Employment: Alternatives for a Metropolitan Region.*

Charles Bernard Daniels, B.A. Kansas State University, 1964; M.A. Kansas State University, 1966; Ph.D. Stanford University, *An Investigation of the Influence of Racial Segregation on Housing Prices in the Oakland, California Housing Market.*

Bruce Weber, B.A. Seattle University, 1965; Ph.D. University of Wisconsin-Madison, *Trickling Down: The Responsiveness of Rural and Rural Poor Family Income and Labor Supply to Regional Economic Growth.*

Charles Victor Anthony White, B.A. University of Connecticut, 1966; M.A. University of Connecticut, 1967; Ph.D. Ohio State University, *Supply Response and Interregional Competition in the Midwest Dairy Industry: An Econometric Analysis.*

XVIII. RESEARCH METHODOLOGY

Jose Enrique Fernandez, B.S. Universidad Agraria, 1966; M.S. North Carolina State University, 1967; Ph.D. Oregon State University, *Treatment of Autocorrelated Disturbances in Economic Functions.*

David H. Harrington, B.S. Cornell University, 1959; M.S. University of New Hampshire, 1964; Ph.D. Purdue University, *Quadratic Input-Output Analysis: Methodology for Empirical General Equilibrium Models.*

Anthony Cameron Lewis, B.S.A. Lincoln College, New Zealand, 1967; M.S.A. Lincoln College, New Zealand, 1970; Ph.D. Purdue University, *Experiments in the Implementation of a Convex Programming Algorithm.*

Charles Lloyd MacDonald, B.S. Oklahoma State University, 1959; M.S.E. University of Michigan, 1961; Ph.D. University of California, *Instrument /Target Relationships for Static and Dynamic Fixed Target Policy Models.*

Haruo Onishi, B.S. Kyoto University, 1965; M.S. Kyoto University, 1967; Ph.D. University of Illinois, *Spatial and Temporal Resource Allocation Methods for Agricultural Watershed Planning.*

XIX. TECHNOLOGICAL CHANGE

Hans-Peter Binswanger, Certificate of Political Science, University of Paris, France, 1964; Master in Agricultural Production Eidgenoessische Technische Hochschule, Switzerland, 1969; Ph.D. North Carolina State University, *The Measurement of Biased Efficiency Gains in U. S. and Japanese Agriculture to Test the Induced Innovation Hypothesis.*

Kyung Won Lee, B.S. Seoul National University, 1965; M.S. Seoul National University, 1969; Ph.D. University of Illinois, *Multivariate Analysis and Geographical Comparison of the Demand for Grain Dryers in Four Midwestern States.*

Juan C. Martinez, University of Buenos Aires, Licenciate in Econ.; M.S. Iowa State University; Ph.D. Iowa State University, *On the Economics of Technological Change: Induced Innovation in Argentine Agriculture.*

Mitoshi Yamaguchi, B.S. Kyoto University, Japan, 1967; M.S. Kyoto University, 1969; Ph.D. University of Minnesota, *Technical Change and Population Growth in the Economic Development of Japan.*

XX. TRADE

Malcolm D. Bale, B.S. Massey University, New Zealand, 1967; M.S. Iowa State University, 1969; M.A. University of Wisconsin-Madison, 1971; Ph.D. University of Wisconsin-Madison, *Adjustment to Freer Trade: An Analysis of the Trade Expansion Act of 1962.*

Andrew Henry Parnes, B.A. Williams College, 1967; M.A. Stanford University, 1969; M.A. Stanford University, 1970; Ph.D. Stanford University, *Export Instability and the Direction of Trade.*

XXI. OTHER

(INTERNATIONAL TRADE)

Roberto Castro-Suarez, Agricultural Eng., Agrarian University, Peru, 1962; Inguinero Agronomo, Agrarian University, 1964; M.E. North Carolina State University, 1970; Ph.D. North Carolina State University, *Expected Effects of Changing United States Tariffs on Winter Green Peppers.*

Grant MacDonald Scobie, B.Ag.Sc. Massey University, New Zealand, 1963; M.Ag.Sc. University of New England, Australia, 1969; Ph.D. North Carolina State University, *The Effects of Changes in the Protective Structure on the Exchange Rate: An Analysis of the New Zealand Foreign Exchange Market.*

Ewen Maclellan Wilson, B.S. Wye College, 1965; M.S. West Virginia University, 1970; Ph.D. North Carolina State University, *An Elasticity Analysis of the Rhodesian Trade Embargo.*

(TRANSPORTATION)

Robert J. Tosterud, B.S. North Dakota State University, 1968; M.S. North Dakota State University, 1969; Ph.D. University of Manitoba, *A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis.*

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Geoffrey Harvey Jackson
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Charles Alexander Robertson
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Ali Ben Zaid Salem
Michael Gerald Galton Schluter
Leonard A. Shabman
Richard Lynn Shortlidge, Jr.
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The principal activities of the association include the following:

- publishing the AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS;
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